NPS55-84-003

NAVAL POSTGRADUATE SCHOOL

Monterey, California

HP-41C PROGRAMS AND INSTRUCTIONS FOR PROBABILITY AND STATISTICS

by

Peter W. Zehna

February 1984

Approved for public release; distribution unlimited.

Prepared for:

Naval Postgraduate School
Monterey ,California 93943

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Commodore R. H. Shumaker
Superintendent

David A. Schrady
Provost

This report was prepared by:

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NPS55-84-003	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HP-41C PROGRAMS AND INSTRUCTIONS FOR PROBABILITY AND STATISTICS		5. TYPE OF REPORT & PERIOD COVERED Technical
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Peter W. Zehna		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, Ca 93943		12. REPORT DATE February 1984
		13. NUMBER OF PAGES 108
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HP Programs
Probability and Statistics
Calculator Programs

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A compendium of programs and instructions to solve problems typically encountered in probability and statistics. Programs are designed to operate directly on the HP-41C family of hand-held calculators.

HP-41C PROGRAMS AND INSTRUCTIONS
FOR
PROBABILITY AND STATISTICS

by

Peter W. Zehna

INTRODUCTION

The purpose of this report is to make available a set of programs and the corresponding user instructions so that the problem material found in the writer's textbooks, "Probability by Calculator and Statistics by Calculator* (hereafter referred to, respectively, as ZP and ZS) may be resolved using the HP-41C calculator. In particular, this means that courses using those textbooks, written entirely around the TI-59, need no longer be restricted to that particular machine as a prerequisite. It is almost essential, however, that the HP user have in his or her possession either the HP-41CV, or the HP-41C with the quad memory module installed, along with a card reader for recording magnetic cards. Also, as with the TI-59, it will be necessary to insert the HP applications module STAT PAC for use with the programs in ZS. No additional module is required for ZP.

The original intention was to write the HP programs in such a way that the TI user instructions could be used with little or no modification. That program was about 90% successful so that, in general, storage in various registers are identical as are the main subroutines labeled with user defined keys (with HP a,b,c, etc., replacing TI A', B', C', etc. in a natural way). There are, however, some special problems created by the differences in the two machines (RPN not being one of them, by the way) that made it impossible to be 100% successful in that endeavor. For example, the TI random number generator could not be duplicated in the HP because of the difference in accuracy of the two machines. Since the TI carries more significant figures internally than the HP, and that internal carriage is used to generate successive seeds for repeated applications, the two machines soon differ in their output. For true applications of random number generation that would be insignificant, even a desirable difference perhaps, but for tutorial purposes, which is the main intent of the books, that makes it impossible to verify answers and that is a serious drawback for the learner. Otherwise, the difference in accuracy created no special problems. The FIX 4 format is used in all of the HP output to follow and it will be found that the corresponding answers then agree to within 4 decimal places (the maximum usually presented in ZP and ZS) of the published answers given in the two books, almost without exception.

Writing the HP programs to utilize essentially the same user instructions as the TI meant not being able to take full advantage of the superior alphanumerics and prompting facility of the HP41-C. The user may well want to adjust the programs presented here to take better advantage of that option but should of course adjust the user instructions accordingly. That particular feature in itself creates some special problems with regard to the use of HP applications modules like STAT PAC. Almost all of the programs in that module contain pauses for prompts from the user. Unfortunately, when such programs are called as subroutines within a calculator program, there is no automatic return from the module program to the parent one. Much of the success of the TI programs depended on precisely this feature utilizing the canned programs available in the master module for ZP and the statistics module for ZS. This made it necessary to replace several of the programs in the HP STAT PAC that would otherwise have been used, as well as to supply several key programs, such as the t and F distributions, that were missing. Fortunately, the massive memory capability furnished by the HP quad memory made it possible to furnish these and still have enough room for the main programs of interest. For ZS then, a special program called ZSTAT has been supplied for which there

*Prentice-Hall, Inc., Englewood Cliffs, NJ, 1982

is no direct TI analogue. The reader may view this as simply an addition to the HP STAT PAC in order to bring it more in line with the TI statistics module utilized throughout ZS.

In order to follow the textbooks as closely as possible with the least amount of cross-referencing, the following format will be followed. Starting with ZP, each chapter or section for which a separate program exists will be discussed separately starting on a new page. After pointing out any general differences that may exist for that chapter or section including the illustrative examples contained therein, the HP version of the User Instructions for that program will be added, together with a set of examples for each subroutine such as presently found in the books for the TI programs. These model examples will show exactly what the user may expect to see in the display upon executing each step. In each case, the reader will find, in addition to the Register Contents as currently published in the textbooks, a set of assignments used by the program along with a listing of labels used (which may also be seen in the complete listing of the programs in the appendix).

The reader should remember to assign, record (and subsequently read) the magnetic cards in USER mode so as to preserve those assignments. In those assignments, we often use lower case versions of capital letters even when they do not, technically, exist. Thus, [i] is used for the alphanumeric [<] since the latter is located above [I] and is effected by pressing the gold shift key, then [I]. Similar remarks apply to [g] (really [%]), [h] (really [÷]) and [j] (really [>]). Of course [a], [b], [c], etc. are actually listed in the alpha keyboard.

Since the [X<>Y] key is used in so many programs, and its execution is considerably slower in USER mode, it is advisable to assign the function X<>Y to this key at the start of a session. Such an assignment cannot be made permanent in the programs, but will remain in effect unless the master clear is used.

Section 1.3: The Calculator

It is assumed here that the reader is reasonably familiar with the Owner's Handbook and Programming Guide for the HP-41C. The general remarks found in this section apply to the HP as well. It has already been remarked that a card reader will be needed to follow the program outlined here. It is possible to do without the magnetic cards for some of the programs since they may be keyed in once and the continuous memory feature of the HP will preserve them. But even that generous memory allowance will soon be used up and programs will have to be replaced to follow all of the subroutines presented in these textbooks. The magnetic cards removes the necessity of having to re-key so many separate programs. Guidelines for recording magnetic cards will be found in the Card Reader handbook and should be consulted.

Section 1.4: The Programs

Many of the remarks in this section will not apply directly to the HP calculator and, again, the Owner's Handbook should be consulted for specifics regarding the related keys. The programs will appear in print-out (see Appendix) as numbered steps with the corresponding mnemonic code (no key code as with the TI). Most are self-explanatory and the Function Index given in the back of the Handbook will be found very helpful should the reader encounter any that are not immediately recognized. Naturally, the programs should be identical with the listings given in the Appendix before any recording takes place.

Section 2.4: Counting Problems

The internal function FACT in the HP will replace the use of label C in Pgm 16 of the TI to display factorials as discussed on page 21. That function has exactly the same restriction, namely, that n must be any positive integer between 0 and 69 inclusive, displaying OUT OF RANGE for larger values. There are no internal programs to handle permutations and combinations directly so they have been programmed in the first card program labeled ZP2. You will find the instructions under Steps 7 and 8. Each scheme prompts you for an input of first N and then R to compute the corresponding values. (The HP alphanumerics do not permit lower case letters so the notation differs just slightly from the book.) With these routines, the answers to the problems in this section may be verified.

Section 2.5: Conditional Probability

The rest of program ZP2 has to do with Bayes probabilities and the instructions match those for the TI exactly (with a,b,c, etc. replacing A',B',C') as previously remarked.

ZP2 (Assigned [e])	USER INSTRUCTIONS (HP)			SIZE $\geq$ 090
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Initialization	xxx	[e]	0.0000
2.	Input probabilities (Repeat for $j = 1,2,\ldots, k$) NOTE: If $Pr(C_j) \equiv 1/k$, use Step 2'	$Pr(E\|C_j)$ $Pr(C_j)$	[A] [R/S]	j j
2'.	a. Input partition size b. Input given priors	k $Pr(E\|C_j)$	[E] [R/S]	1/k j
3.	Compute Bayes posterior probability $Pr(C_i\|E)$	i	[B]	$Pr(C_i\|E)$
4.	a. Initialize for sensitivity analysis b. Recall given priors c. Input new cause probabilities (Repeat for $j = 1,2,\ldots,k$) NOTE: If new $Pr(C_j) \equiv 1/k$, use Step 4'	xxx New $Pr(C_j)$	[e] [D] [R/S]	0.0000 $Pr(E\|C_j)$ j
4'.	a. Initialize b. Input partition size	xxx k	[e] [d]	0.0000 k
5.	Compute Pr(E) (Law of Total Probability)	xxx	[a]	Pr(E)
6.	<u>Birthday Problem</u> (E_k is the event that two or more among k people in a room have the same birth date.)	k	[C]	$Pr(E_k)$
7.	Calculate $P(\substack{N\\R})$	 N R	[b] [R/S] [R/S]	N = ? R = ? $P(\substack{N\\R})$
8.	Calculate $C(\substack{N\\R})$	 N R	[c] [R/S] [R/S]	N = ? R = ? $C(\substack{N\\R})$

Register Contents

00	Used	10		20	$Pr(E\|C_1)$
01		11	Used	21	$Pr(C_1)$
02		12	Used	22	$Pr(E\|C_2)$
03	k	13	1/k	23	$Pr(C_2)$
04	$\Sigma Pr(E\|C_j)$	14	Used	24	.
05		15		25	.
06		16		26	.
07		17		27	
08		18		28	
09		19		29	

Assignments

ZP2	e

Labels Used

02	A	a
03	B	b
04	C	c
05	D	d
08	E	
09		
10		
11		
12		

EXAMPLES ZP2 (1) Suppose in medical diagnostics a particular symptom (E) always occurs in conjunction with three diseases C_1, C_2, C_3 with respective probabilities 0.90, 0.09 and 0.009 or else occurs rarely (0.001) with no apparent reason (C_4) at all. National statistics show that most people are free of the three diseases, $Pr(C_4) = 0.99$, and disease C_1 is fairly rare, $Pr(C_1) = 0.0001$. Diseases C_2 and C_3 occur with respective probabilities 0.0045 and 0.0054.

Bayes Format:

Events	Conditional Priors	Cause Probabilities	Conditional Posteriors
C_1 = Disease #1	0.90	0.0001	0.0587
C_2 = Disease #2	0.09	0.0045	0.2641
C_3 = Disease #3	0.009	0.0054	0.0317
C_4 = No Disease	0.001	0.9900	0.6455
E = Symptom			$Pr(E) = 0.0015$

Calculator Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
Step 1		[e]	0.0000	Initialization
Step 2	.9	[A]	1.0000	First conditional prior
"	.0001	[R/S]	1.0000	Shows one pair entered
"	.09	[A]	2.0000	Second conditional prior
"	.0045	[R/S]	2.0000	Shows two pairs entered
"	.009	[A]	3.0000	Third conditional prior
"	.0054	[R/S]	3.0000	Shows three pairs entered
"	.001	[A]	4.0000	Fourth conditional prior
"	.99	[R/S]	4.0000	Shows four pairs entered
Step 3	1	[B]	0.0587	First conditional posterior
"	2	[B]	0.2641	Second conditional posterior
"	3	[B]	0.0317	Third conditional posterior
"	4	[B]	0.6455	Fourth conditional posterior
Step 4		[a]	0.0015	Probability of E

EXAMPLES ZP2 (2) A manufacturer of hand-held calculators has three different assembly plants F, M and T. These three plants historically produce defective items with respective probabilities 0.01, 0.02 and 0.04. Plant F produces 50% of the calculators while plants M and T produce, respectively, 30% and 20%.

Original Bayes Format:

Events	Priors	Causes	Posteriors
C_1 = Plant A	0.01	0.50	0.2632
C_2 = Plant B	0.02	0.30	0.3158
C_3 = Plant C	0.04	0.20	0.4211
E = Defective			Pr(E) = 0.0190

Calculator Solution for Changing Priors to $p_i \equiv 1/3$ (after original entry):

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
Step 4a.		[e]	0.0000	Initialization
Step 4b.		[D]	0.0100	First prior displayed
Step 4c.	1/3	[R/S]	1.0000	First cause prob. changed
Step 4b.		[D]	0.0200	Second prior displayed
Step 4c.	1/3	[R/S]	2.0000	Second cause prob. changed
Step 4b.		[D]	0.0400	Third prior displayed
Step 4c.	1/3	[R/S]	3.0000	Third cause prob. changed
Step 3	1	[B]	0.1429	New $Pr(E\|C_1)$
"	2	[B]	0.2857	New $Pr(E\|C_2)$
"	3	[B]	0.5714	New $Pr(E\|C_3)$

Alternate Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
Step 4'a.		[e]	0.0000	Initialization
Step 4'b.	3	[d]	3.0000	Partition size entered
Step 3	1	[B]	0.1429	New $Pr(E\|C_1)$
"	2	[B]	0.2857	New $Pr(E\|C_2)$
"	3	[B]	0.5714	New $Pr(E\|C_3)$

EXAMPLES ZP2 (3) Calculate $P\binom{10}{2}$, 4! and $C\binom{52}{5}$.

Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
Step 7.		[b]	N=?	Prompts for entry of N
	10	[R/S]	R=?	Asks for the value of R.
	2	[R/S]	90.0000	Display $P\binom{10}{2} = 90$.
		[b]	N=?	Initializes permutation routine.
	4	[R/S]	R=?	Asks for the value of R.
	4	[R/S]	24.0000	Displays $4! = P\binom{4}{4}$.
		[c]	N=?	Initializes combination routine.
	52	[R/S]	R=?	Prompts for entry of R=5.
	5	[R/S]	2,598,960	Displays $C\binom{52}{5}$, the total number of poker hands.

NOTE: 4! may also be computed by executing the function FACT.

Section 3.2: Moments of a Random Variable

Just as with ZP2, the HP version of ZP3.2 (denoted ZP3-2 since a period may not be used in an ALPHA label) is almost exactly the same as the TI version. In the discussion of the program on page 57, you may ignore the warnings concerning capacity limitations and repartitioning the calculator. Sizing the HP to allow for more memory registers will accomplish the same thing. In any case, such problems will never arise in the applications presented here. You might observe the use of the alternate HP form, [X<>Y], for the X exchange Y key throughout this report. This is merely a concession to ease of printing. (HP Y-register is always used in place of TI T-register)

The one place where there is serious departure from the TI-59 is in repeated application of LABS. To erase a previous application with the TI, one need only over-write the old algorithm with the new one, paying no attention to what may or may not remain when the new algorithm is finished with a RETURN instruction. But, because algorithms must be created as individual subroutines with the HP, erasing is not so simple. At Step 4f. the beginning of the old algorithm is displayed at program step 88. The steps from this point on need to be erased and this may be accomplished with the internal function DEL. Then the new algorithm may be inserted where the old one resided and the program will function for the new case. As suggested in the footnote to the user instructions that follow, you might assign DEL to a label like [g] if a lot of erasing is to be done. Unfortunately, the DEL function cannot be recorded as an instruction in program memory so this will only be helpful for given session.

On page 59, an HP version of the algorithm for g(x)=3x+19 would be

RCL 09,3,*,19,+,RTN

and g(x)=(x*x-4)/(6x+7) could be keyed in as

4,RCL 09, ENTER,*,-,CHS,RCL 09,6,*,7,+,/,RTN

Here we have taken the liberty of using the printed symbol / for the division operator and the symbol * for multiplication.

Section 3.3: Hypergeometric and Binomial Distributions

Section 3.4: Other Discrete Distributions

For both of these sections, the HP programs are practically identical with the TI programs. The basic difference is that the HP initialization step is to press [e] instead of RST. Having so used label e , label J is used for the number of trials, Y , to r^{th} success at NB5 in program ZP3-4.

ZP3-2 (Assigned [e])	USER INSTRUCTIONS (HP)			SIZE 060
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Distribution Entry			
	a. Initialize		[e]	0.0000
	b. Enter (in order) x_i, p_i	x_i	[A]	x_i
	(Repeat for $i = 1,2,\ldots,N \leq 20$;	p_i	[R/S]	i.0000
	$x_1 < x_2 < \ldots < X_N$)			
2.	Calculate P(x)	x-code	[C]	P(x)
	(x-code = j where $x_j \leq x < x_{j+1}$)			
3.	Calculate E(X), V(X)		[E]	E(X)
	(after Step 1)		[X<>Y]	V(X)
4.	Calculate E[g(X)], V[g(X)]			
	(after Step 1)			
	a. Initialize		[GTO][B]	x.xxxx
	NOTE: It is understood that [ALPHA] must be used for label B.			
	b. Enter Program Mode		[PRGM]	87 LBL B
	c. Key in g(x) where $x \in R_{09}$		-	
	(Avoid labels already in use, end with RTN)		-	
			-	
	d. Exit Program Mode		[PRGM]	x.xxxx
	e. Calculate Moments.		[D]	E[g(X)]
			[X<>Y]	V[g(X)]
	f. To ERASE Algorithm in [B], complete Steps a,b; then		[SST]	88 yy
			[g]	DEL ___
	let nnn be at least as large as the number of Steps in [B]†		nnn [PRGM]	87 LBL B x.xxxx

†For repeated uses of this step use ASN to assign DEL to g(%).

Register Contents

00	Used	10	P(x)	20	x_1
01	x-address	11		21	p_1
02	p-address	12		22	x_2
03	N	13		23	p_2
04	$x_i p_i$	14		24	x_3
05	$x_i^2 p_i$	15		25	p_3
06	Mean	16		26	.
07	2nd Moment	17		27	.
08	Variance	18		28	.
09	x-value	19		29	

Assignments

ZP3-2	e

Labels Used

01	A
02	B
03	C
04	D
05	E
06	
07	

EXAMPLE ZP3-2. X = # daily sales of a morning newspaper at a local drugstore.

x:	0	1	2	3	4	5
p(x):	0.01	0.01	0.04	0.03	0.67	0.24

Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
Step 1a.		[e]	0.0000	Initialization
Step 1b.	0	[A]	0.0000	Enter first x-value
"	.01	[R/S]	1.0000	Enter first p-value
"	1	[A]	1.0000	Enter second x-value
"	.01	[R/S]	2.0000	Enter second p-value
"	2	[A]	2.0000	Enter third x-value
"	.04	[R/S]	3.0000	Enter third p-value
"	3	[A]	3.0000	Enter fourth x-value
"	.03	[R/S]	4.0000	Enter fifth p-value
"	4	[A]	4.0000	Enter fifth x-value
"	.67	[R/S]	5.0000	Enter fifth p-value
"	5	[A]	5.0000	Enter sixth x-value
"	.24	[R/S]	6.0000	Enter sixth p-value

Calculate P(4.5) (x-code = 5 since $x_5 \leq 4.5 < x_6 = 5$)

Step 2	5	[C]	0.7600	Note that $x_1=0$ so that $x_5=4$.

Calculate $\mu = E(X)$ and $\sigma^2 = V(X)$.

Step 3		[E]	4.0600	Display $\mu = 4.06$
		[X<>Y]	0.6764	Display $\sigma^2 = 0.6764$

Calculate E[g(X)] and V[g(X)] where g(x) = 25x - 50 is net daily income.

Step 4a.		[GTO]	GTO__	Initialize
		[ALPHA]	GTO__	
		[B]	GTO B_	
		[ALPHA]	x.xxxx	
Step 4b.		[PGRM]	87 LBL B	
Step 4c.		[RCL]	88 RCL __	
		09	88 RCL 09	Brings current x-value into
		25	89 25 _	R_X

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
		[x]	90 *	Multiplies x by 25,
		50	91 50_	and subtracts
		[-]	92 -	50.
		[RTN]	93 RTN	Ends algorithm.
Step 4d.		[PRGM]	x.xxxx	Exit Program mode.
Step 4e.		[D]	51.5000	Calculates "average" daily net income as 51.5 cents.
		[X<>Y]	422.7500	Exhibits variance in cents^2.
		[USER]$\sqrt{x}$	20.5609	Shows σ as 20.56 cents.

Calculate E[g(X)] and V[g(X)] where g(x) is daily profit.

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
Step 4f.		[GTO]	GTO__	Initialize
		[ALPHA]	GTO_	
		[B]	GTO B_	
		[ALPHA]	x.xxxx	
		[PGRM]	87 LBL B	Enters ZP-3.2 program at B.
		[SST]	88 yy	Locates first step of last algorithm
		[g]	DEL ___	Prepares to delete algorithm steps.
		010	87 LBL B	Deletes to END statement.
Step 4b.		2	88 2_	Enters 2 for comparison with x.
		[RCL]09	89 RCL 09	Retrieves x.
		[X>Y?]	90 x>y?	Asks if x>y?
		[GTO]20	91 GTO 20	Proceeds to subroutine to be constructed for evaluating g(x).
		0	92 0 _	Otherwise g(x)=0
		[RTN]	93 RTN	Ends that part of algorithm
		[LBL]20	94 LBL 20	Prepares to define subroutine.
		25	95 25	g(x) = 25x - 50.
		[x]	96 *	A return is not necessary
		50	97 50	since it is controlled by END.
		[-]	98 -	
		[PRGM]	x.xxxx	Exits program mode.
Step 4c.		[D]	52.2500	Calculates and exhibits "average" daily profit of 57.25 cents.
Step 4d.		[X<>Y]	313.6875	Shows profit variance.

ZP3-3 (Assigned [e])	USER INSTRUCTIONS (HP)			SIZE 030
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	<u>Hypergeometric</u> <u>Distribution</u>			
H1	Initialization		[e]	0.0000
H2	Enter Parameters	N	[STO]14	N
	($n \leq N$ and $0 < M \leq N$)	M	[STO]15	M
		n	[STO]13	n
H3	Calculate $P(k) = Pr(X \leq k)$	k	[A]	P(k)
	$p(k) = Pr(X = k)$		[X<>Y]	p(k)
H4	Calculate $Q(k) = Pr(X > k)$	k	[a]	Q(k)
	$p(k) = Pr(X = k)$		[X<>Y]	p(k)
	NOTE: Repeat H_3 and/or H_4 as often as desired.			
	<u>Binomial</u> <u>Distribution</u>			
B1	Initialization		[e]	0.0000
B2	Enter Parameters ($M \leq N$)	N	[STO]14	N
		M	[STO]15	M
		n	[STO]13	n
B3	Calculate $P(k) = Pr(X \leq k)$	k	[B]	P(k)
	$p(k) = Pr(X = k)$		[X<>Y]	p(k)
B4	Calculate $Q(k) = Pr(X > k)$	k	[b]	Q(k)
	$p(k) = Pr(X = k)$		[X<>Y]	p(k)
	NOTE: Repeat B_3 and/or B_4 as often as desired.			
E	Display E(X) and V(X) (following any application of $H_3(H_4)$ or $B_3(B_4)$)		[E] [X<>Y]	E(X) V(X)

Register Contents

00		10	P(x)	20	Used
01	N/n for PMTON	11	μ	21	1 - M/N
02	r/k CMBON	12	σ^2	22	M/N
03		13	n	23	Used
04		14	N	24	N-M
05		15	M	25	
06	Used; p(k)	16	p(0)	26	
07	Used; p(k)	17		27	
08	Used	18		28	
09		19		29	

Assignments

ZP3-3	e
PMTON	i
CMBON	h

Note: PMTON and CMBON require storage of n in R_{01} and k in R_{02}, for execution using XEQ ' '

Labels Used

01	A	a
02	B	b
03	E	
04		
05		
06		
07		
08		
11		
12		
13		
19		

EXAMPLES ZP3-3. An urn contains five black balls and seven white balls.

(1) A sample of size 3 is drawn without replacement. Calculate the probability of obtaining exactly two black balls, at most two black balls and at least two black balls. Answers are, respectively, p(2)=0.32, P(2)=0.95 and Q(1)=0.36. (See display below.)

(2) Repeat (a) for a sample drawn with replacement. Answers are, respectively, p(2)=0.30, P(2)=0.93, Q(1)=0.38.

(3) For each of (a) and (b) determine the mean and variance of X, the number of black balls in the sample.

Ans. (a) $\mu = 1.25$, $\sigma^2 = 0.60$; (b) $\mu = 1.25$, $\sigma^2 = 0.73$.

Solution (1), (3):

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
H1		[e]	0.0000	Only necessary when starting a new problem.
H2	12	[STO]14	12.0000	
	5	[STO]15	5.0000	
	3	[STO]13	3.0000	
H3	2	[A]	0.9545	Displays CDF P(2) first
		[X<>Y]	0.3182	Displays p(2).
H4	1	[a]	0.3636	Displays Q(1). No re-initialization necessary.
E		[E]	1.2500	Displays mean and variance
		[X<>Y]	0.5966	

Solution (2), (3):

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
B1		[e]	0.0000	Signals the start of a new program even though the same parameters are involved (B2 unnecessary)
B3	2	[B]	0.9277	Binomial CDF differs from H_3
		[X<>Y]	0.3038	Binomial p(2).
B4	1	[b]	0.3762	$Q(1) = Pr(X > 1) = Pr(X \geq 2)$
E		[E]	1.2500	Mean
		[X<>Y]	0.7292	Variance

ZP3-4 (Assigned [e])	USER INSTRUCTIONS (HP)			SIZE 030
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	Binomial Distribution			
bin 1	Initialization		[e]	0.0000
bin 2	Enter Parameters	n	[STO]13	n
		p	[STO]22	p
bin 3	Calculate P(k) = Pr(X $\leq$ k)	k	[B]	P(k)
			[X<>Y]	p(k)
bin 4	Calculate Q(k) = Pr(X > k)	k	[b]	Q(k)
			[X<>Y]	p(k)
	NOTE: Repeat 3 and 4 as often as desired			
	Poisson Distribution			
PO1	Initialization for Poisson		[e]	0.0000
PO2	Enter Parameters	t	[STO]13	t
		λ	[STO]22	λ
PO3	Calculate P(k) = Pr(X $\leq$ k)	k$\geq$0	[C]	P(k)
			[X<>Y]	p(k)
PO4	Calculate Q(k) = Pr(X > k)	k$\geq$0	[c]	Q(k)
			[X<>Y]	p(k)
	NOTE: See Note in bin			
	Negative Binomial Distribution			
NB1	Initialization for Negative Binomial		[e]	0.0000
NB2	Enter Parameters	r	[STO]13	r
		p	[STO]22	p
NB3	Calculate P(k) = Pr(X $\leq$ k)	k$\geq$0	[A]	P(k)
	p(k) = Pr(X = k)		[X<>Y]	p(k)
NB4	Calculate Q(k) = Pr(X > k)	k$\geq$0	[a]	Q(k)
	p(k) = Pr(X = k)		[X<>Y]	p(k)
NB5	Calculate P(k) = Pr(Y $\leq$ k)	k$\geq$r	[J]	P(k)
	p(k) = Pr(Y = k)		[X<>Y]	p(k)
	NOTE: See Note in bin; Y = X+r = # Trials			

ZP3-4	USER INSTRUCTIONS (HP)			
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	Geometric Distribution			
G1	Initialization for Geometric		[e]	0.0000
G2	Enter Parameter	p	[STO]22	p
G3	Calculate $P(k) = Pr(Y \leq k)$	$k \geq 1$	[D]	P(k)
	$p(k) = Pr(Y = k)$		[X<>Y]	p(k)
G4	Calculate $Q(k) = Pr(Y > k)$	$k \geq 1$	[d]	Q(k)
			[X<>Y]	p(k)
	NOTE: See note under bin.			
E	Display E(X) and V(X) (after any of the foregoing routines)		[E] [X<>Y]	E(X) V(X)

Register Contents:

00	Used	10	z	20	Used
01		11	μ	21	q
02		12	σ^2	22	$p(\lambda)$
03		13	n(t,r)	23	
04		14		24	
05		15		25	
06	Used (p(k))	16	p(0)	26	
07	Used (p(k))	17		27	
08		18		28	
09		19		29	

Assignments

ZP3-4 | e

Labels Used

05	A	a
07	B	b
08	C	c
11	D	d
13	E	
14	J	
15		
18		
19		
20		
29		

EXAMPLES ZP3-4

(1) (Binomial model) The probability of hitting a target in a single trial is 0.3. Suppose 10 independent firings are made. Calculate the probability of 3 hits, no more than 4 hits, at least 6 hits and the mean and variance of the number of hits.

Solution (1), (3):

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
bin 1		[e]	0.0000	Initialize program.
bin 2	10	[STO]13	10.0000	Enter parameters.
"	.3	[STO]22	0.3000	
bin 3	3	[B]	0.6496	Display the CDF at 3.
		[X<>Y]	0.2668	Required probability p(3).
bin 3	4	[B]	0.8497	Repeating to find P(4).
bin 4	5	[b]	0.0473	Required Q(5) = Pr($X \geq 6$)
E		[E]	3.000	Mean value np = 3.
		[X<>Y]	2.1000	Variance of X = npq.

(2) Poisson model) Telephone calls arrive at a switchboard at the rate of 10 per hour. What is the probability of at most 3 calls in the next 20 minutes? Exactly 3? The mean number of calls?

Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
PO1		[e]	0.0000	Initialize program.
PO2	0.3333	[STO]13	0.3333	Enter total time period 20 min.
"	10	[STO]22	10.0000	Enter rate λ = 10 per hour.
PO3	3	[C]	0.5730	P(3) = Pr($X \leq 3$).
		[X<>Y]	0.2202	p(3) = Pr(X = 3).
E		[E]	3.3333	Mean number of calls in 20 mins.

(3) (Negative Binomial model) A fly fisherman estimates that his probability of catching a fish on a given cast of his rod is 0.05. He decides to keep trying until he catches three fish. What is the probability that he will need to cast at least 10 times and what is the expected number of failures? What is the probability of 9 trials? The mean number of trials?

Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
NB1		[e]	0.0000	Initialize program.
NB2	3	[STO]13	3.0000	Enter r parameter of 3.
"	.05	[STO]22	0.0500	Enter probability of obtaining 1.
NB4	6	[a]	0.9916	Probability that the number of failures is at least 7, Q(6).
		[X<>Y]	0.0026	Probability of exactly 6 failures.
E		[E]	57.0000	Mean number of failures.
NB5	9	[J]	0.0084	Probability of no more than 9 trials.
		[X<>Y]	0.0026	Probability of exactly 9 trials.

(4) Geometric model) An item has failure probability 0.005 and is cycled until it fails. What is the expected number and standard deviation of the number of cycles? What is the probability that number exceeds 10?

Solution:

G1		[e]	0.0000	Initialize program.
G2	.0005	[STO]22	0.0005	Enter single parameter.
G3	10	[d]	0.9950	Displays CCDF at 10, Pr(Y > 10).
E		[E]	2000.0000	Mean cycles to failure.
		[X<>Y]	3,998,000	Variance.
		[USER]$\sqrt{x}$	1999.4999	Standard deviation.
		[e]	0.0000	Clears program.

Section 4.3: Normal Distribution

The user instructions for the HP version of ZP4 are practically identical to those for TI given in the book. Label [J] is used for initialization in place of RST; otherwise, pressing the same labels produces the same results. Using the parameter choices 0 and 1 at step N1 in ZP4 replaces ML-14 in the TI master module everywhere the discussion refers to the latter starting on page 109.

Section 4.4: Uniform Family; Sampling

As previously indicated, the serious departure from the TI format occurs in the random number generator and consequently, both the instructions and the results will differ from those published in the book. The departure begins on page 121. The random number generator adopted for the HP programs is one developed by Don Malm for the HP-65 User's Library and is referred to on page 24 of the HP-41C Standard Applications manual. The algorithm used is the simple one.

$$r_{n+1} = \text{FRC } (9821 * r_n + .211327)$$

It allegedly will generate one million random numbers when a seed between 0 (inclusive) and 1 is used. This random number generator is initialized by pressing [I] whereupon you are prompted for a seed which is then entered with [R/S] instead of TI [E']. For some degree of uniformity with the TI illustrations, you may use a decimal point in front of each of the seeds given in the book, such as .419 in Example 4.10 on page 121. Subroutine RNDMU, assigned to label [i], replaces [SBR] [D.MS] and outputs a random number from the unit interval. For this illustration, the output of the HP program is .2104 instead of 0.65816 as listed, and the corresponding value of x will accordingly be 15,589.

In example 4.11, ML-15 is used to generate normal deviates. Here, Step N6, programmed as label [G] of the Normal Distribution program in ZP4, may be used in its place. For the example, using a seed of .793, the output should be 56.2958. (Of course, the parameters must be suitably stored by Step N1 to begin with.)

Continuing on page 122, the subroutine [P→R] replaces the TI key [$\bar{x}$], while [R→P] replaces [INV] [$\bar{x}$]. In Example 4.12, the sample values will be 47,30,56,48 with a mean of 47.3 and a standard deviation of 10.4. The next successive values are 49,45,57,50,61 with a mean of 49.8 and a standard deviation of 8.5. In Example 4.15, the ten successive values will be 727,708,417, 3401,326,213,1770,686,825,2783 with running counts checked in Register 06 rather than 03. The mean will be 1147.9 rather than the published 1311. In Example 4.16, using a seed of .66, the successive values will be 0,2,4,6,2.

If you have been able to check these examples, then, while your answers will differ from the published ones whenever random number generation is called in the problems that follow, you may rely on the results nevertheless.

ZP4 (Assigned [J]) USER INSTRUCTIONS (HP) SIZE 030

Σ REG 01

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	<u>Exponential Distribution</u>			
E1	Initialization		[J]	0.0000
E2	Enter Parameter	λ	[STO]22	λ
E3	Compute P(x) and Q(x)	$x \geq 0$	[E]	P(x)
	NOTE: λx must not exceed 228		[X<>Y]	Q(x)
E4	Calculate 100(1-α)th Percentile	α	[e]	x_α
	NOTE: Repeat E_3 and E_4 at will			
E5	Generate sample of size n			
	a. Initialize Random Number Generator		[I]	SEED?
	b. Enter Seed ($0 \leq$ Seed < 1)	Seed	[R/S]	Seed
	c. Execute Step E2			λ
	d. Generate x (Repeat n times)		[B]	x
	<u>Normal Distribution</u>			
N1	Enter Parameters	μ	[STO]11	μ
		σ^2	[STO]12	σ^2
N2	Compute P(x) and Q(x)	x	[C]	P(x)
			[X<>Y]	Q(x)
N3	Compute $\Pr(x_1 < X < x_2)$			
	a. Enter x_1	x_1	[D]	$P(x_1)$
	b. Enter x_2 and compute.	x_2	[R/S]	$\Pr(x_1<X<x$
			[X<>Y]	$\Pr(X<x_1)$ $+ \Pr(X>x_2$
N4	Calculate Standard 100(1-α)th Percentile	α	[c]	z_α
NB5	Calculate General 100(1-α)th	α	[d]	x_α
	NOTE: Repeat N_2-N_5 as often as desired			
N6	Generate sample of size n			
	a. Initialize Random Number Generator		[I]	SEED?
	b. Enter Seed ($0 \leq$ Seed < 1)	Seed	[R/S]	Seed
	c. Execute Step N1			
	d. Generate x (Repeat n times)		[G]	x

ZP4	USER INSTRUCTIONS (HP)			
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	Uniform Distribution			
U1	Initialization		[J]	0.0000
U2	Enter Parameters	a	[STO]13	
		b	[STO]14	
U3	Compute P(x) and Q(x)	x	[A]	P(x)
			[X<>Y]	Q(x)
U4	Compute 100(100(1-α)th Percentile	α	[SF]05	xxx
			[A]	x_α
U5	Generate sample of size n from $R_X = \{e_1, e_2, \ldots, e_N\}$ corresponding to LABELS 00, 01,...,K.			
	a. Initialize Random Number Generator		[I]	SEED?
	b. Enter Seed (0 ≤ Seed < 1)	Seed	[R/S]	Seed
	c. Execute Step U2 with a = 0, b = K			
	d. Generate Random Label R		[a]	R
	e. Enter e-value corresponding to R. Repeat d and e for i = 1,2,...,n.	x_i	[R/S]	i
	NOTE 1. Summary stats stored in $R_{01} - R_{06}$.			
	NOTE 2. To generate from $\{A, A+1, \ldots, B\}$ execute steps a-d with a = A, b = B			
M	For each of the above distributions μ and σ^2 may be recovered after computing any P(x).		[b]	μ
			[X<>Y]	σ^2

Register Contents:

00	Used	10	$z = (x-\mu)/\alpha$	20	
01	Used	11	μ	21	
02	by	12	σ^2	22	λ
03	ΣREG	13	$z_\alpha(z)$	23	
04		14	b(K)	24	
05		15	b-a	25	Used
06	p(x)	16		26	Used
07	P(x)	17		27	
08	$P(x_1)-P(x_2)$	18		28	
09	Seed	19		29	

Assignments

ZP4	J
ZCDF	H
GEN-INI	I
RNDMU	i
XBAR	P→R
SD	R→P

Labels Used

03	A	a
07	B	b
09	C	c
11	D	d
12	E	e
15	G	
16		
17		

EXAMPLES ZP4

(1) Time to failure, X, is exponential with failure rate = 0.0001.

a. Determine the reliability at x_o = 100 and at x_o = 500.

b. What would the failure rate have to be to achieve a reliability of 0.99 at 500 hours?

c. Calculate mean and median time to failure and the variance of X.

Solution (1), (3):

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
E1		[J]	0.0000	Initialize exponential subroutine.
E2	.0001	[STO]22	0.0001	Single parameter stored in R_{22}.
E3	100	[E]	0.0100	Displays P(100)
"		[X<>Y]	0.9900	Displays Q(100), the reliability at 100.
E3	500	[E]	0.0488	P(500) displayed.
"		[X<>Y]	0.9512	Q(500) = reliability at 500
E2	500	[STO]22	500.0000	Treating 500 as λ temporarily for computation in b.
E5	.99	[e]	2.0101-05	Value of $\lambda = \ell n(0.99)/500$
E2	.0001	[STO]22	0.0001	Restores true λ in R_{22} for the model.
M		[b]	10,000.0000	Displays mean time to failure
		[X<>Y]	100,000,000	Displays $\sigma^2 = \mu^2$ for this model
E4	0.5	[e]	6931.0000	The median time to failure
E3		[E]	0.5000	Verifies that P(6931) = 0.50.

(2) A standardized test is administered to incoming freshmen at a university. Scores, X, are assumed to be normally distributed and, based on thousands of past scores, it is assumed that $\mu = 100$ and $\sigma^2 = 245$. For an incoming freshman chosen at random what is the probability that the test score will be:
a) greater than 110? b) less than 90? c) between 75 and 125? If only the top 80% of incoming freshmen are to be admitted on the basis of this test, what would the minimum passing score be?

Solutions:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
-		[J]	0.0000	Clears exponential problem.
N1	100	[STO]11	100.0000	Enter the mean value.
"	245	[STO]12	245.0000	Enter the second parameter σ^2.
N2	110	[C]	0.7385	Displays P(110) = Pr(X < 110).
		[X<>Y]	0.2615	Displays Q(110), the required probability
		[RCL]10	0.6389	Shows the standardized value for x = 110, namely, $z = (110-100)/\sqrt{245}$
N2	90	[C]	0.2615	Displays P(90)
N3a	75	[D]	0.9449	Displays Q(75), of minor interest
N3b	125	[R/S]	0.8898	Calculates and displays Pr(75 < X < 125)
		[X<>Y]	0.1102	Displays Pr(X<75) + Pr(X>125).
N5	.80	[d]	86.8291	Displays the 20th percentile for X so that Pr(X>87) = 0.80.

---

(3) The time a passenger must wait for a commuter flight on arrival at an airport is a uniform random variable over an inteval from 0 to 30 minutes.

a. What is the probability that the passenger will have to wait at least 10 minutes for a flight?

b. What waiting time corresponds to a 90% chance of catching a flight?

c. What is the probability that the passenger will wait between 10 and 20 minutes?

d. What is the mean waiting time? σ^2 and σ?

Solutions:

U1		[J]	0.0000	Initialize program (clears all previous work).
U2	0	[STO]13	0.0000	Enters first parameter a = 0 in R_{13}
"	30	[STO]14	30.0000	Enters second parameter b = 3 in R_{14}
U3	10	[A]	0.3333	Displays P(0).
		[X<>Y]	0.6667	Displays the required Q(10).
U4	.90	[SF]05	0.9000	Signals calculator that percentile is coming.
U4		[A]	3.0000	Displays $x_{.90}$
		[A]	0.1000	Verifies that P(3) = .10 so that Q(3) = .9

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
U4	10	[ENTER]	10.0000	Enters difference between 10 and 20 min.
"	30	[÷]	0.3333	Calculates and displays $Pr(10 < X < 20) = (20-10)/30$.
M		[b]	15.0000	Recalls and displays $\mu = 15$ from R_{11}
"		[X<>Y]	75.0000	Displays the variance $\sigma^2 = 30^2/12$
		[USER][$\sqrt{x}$]	8.6603	Displays the value of σ.
		[J]	0.0000	Clears the program.

Chapter 5. BIVARIATE DISTRIBUTIONS

The user instructions are practically identical to those given for the TI-59 so little has to be modified in this chapter. At Step 2 in the HP version a display of moments routine has been added which is effected by pressing [d] followed by successive presses of [R/S]. Of course, these characteristics may also be recalled manually from the respective registers just as instructed in the book.

As with ZP3-2, some modification of the routine for LABS is called for here also. The HP instructions on the matter at Step 3 are reasonably clear. As a footnote, it is advised once more that if you will be involved in a lot of erasing of old algorithms, perhaps it would be advisable to assign the delete function DEL to an unused label, like [g] for a given session. When applying LABS to various algorithms such as those found on page 142, naturally they will have to be programmed in RPN here. It is assumed that the reader is already sufficiently familiar with the HP calculator that the translation for various examples can be made without additional instruction here. Consult the OWNERS HANDBOOK AND PROGRAMMING GUIDE for any required assistance. As one example, the function g(x,y)=(x-1)(y-2) may be programmed at Step 3c as

RCL, 09, 1, -, RCL, 10, 2, -, *, RTN

Other cases can be handled in a similar fashion.

ZP5 (Assigned [e])	USER INSTRUCTIONS (HP)			SIZE 090
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Distribution Entry			
	a. Initialize		[e]	0.0000
	b. Enter in order x_i, y_i, $p(x_i,y_i)$	x_i	[A]	i
	(Repeat for each i through $N \leq 19$)	y_i	[B]	i
	NOTE: $p(x_i,y_i)$ should be positive.	$p(x_i,y_i)$	[C]	i
2.	a. Compile Distribution Characteristics		[E]	ρ
	b. Display Characteristics		[d]	μ_x
			[R/S]	σ_x^2
			[R/S]	μ_y
			[R/S]	σ_y^2
	NOTE: To re-compile, enter N in R_{03} after [e]		[R/S]	σ_{xy}
			[R/S]	ρ
3.	Calculate E[g(X,Y)], V[g(X,Y)] (after Step 1)			
	a. Initialize		[GTO][a]	x.xxxx
	NOTE: It is understood that [ALPHA] must be used for label a			
	b. Enter Program Mode		[PRGM]	147 LBL a
	c. Key in g(x,y) with $x \in R_{09}$,		-	
	$y \in R_{10}$		-	
	(Avoid labels already in use; end with RTN)		-	
	d. Exit Program Mode		[PRGM]	x.xxxx
	e. Calculate Moments		[D]	E[g(X,Y)
			[X<>Y]	V[g(X,Y)]
	f. To ERASE Algorithm in [a], complete Steps a, b; then ...		[SST] [g]	148 yy DEL ___
	(Let nnn be at least as large as the number of steps in [a].)†		nnn	147 LBL a
			[PRGM]	x.xxxx

†For repeated applications, use ASN to assign DEL to g (%).

Register Contents

00	Counter	10	last y	20	x_1
01	$xp(x,y)$	11	μ_X	21	y_1
02	$yp(x,y)$	12	σ_X^2	22	$p(x_1,y_1)$
03	N	13	μ_Y	23	x_2
04	$x^2p(x,y)$	14	σ_Y^2	24	y_2
05	$y^2p(x,y)$	15	σ_{XY}	25	$p(x_2,y_2)$
06	$xyp(x,y)$	16	ρ	26	.
07	$\Sigma\Sigma p_{ij} = 1(g(x,y)p(x,y))$	17	$E[g(X,Y)]$	27	.
08	$\text{lastp}(g^2(x,y)p(x,y))$	18	$V[g(X,Y)]$	28	.
09	last x	19	Used	29	

Assignments

ZP5	e

Labels Used

01	A	a
02	B	d
03	C	
	D	
	E	

EXAMPLES ZP5 (1) Calculate the moments μ_X, σ_X^2, μ_Y, σ_Y^2, σ_{XY} and ρ for the joint distribution of Figure 5-2 duplicated below.

3	0	.2	0	0
2	0	0	.2	0
1	.1	.2	0	.3
y/x	1	2	3	4

Solutions:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
Step 1a		[e]	0.0000	Initialize ZP-5.
Step 1b	1	[A]	1.0000	First x-value for pair (1,1) entered.
"	1	[B]	1.0000	Corresponding y-value is entered.
"	.1	[C]	1.0000	Enter p(1,1) = .1; count of 1 triplet displayed.
"	2	[A]	2.0000	Enter x-value of second pair selected, (2,1).
"	1	[B]	2.0000	Enter corresponding y-value.
"	.2	[C]	2.0000	Enter p(2,1); display shows 2 triplets entered.
"	4	[A]	3.0000	Pass up cell (3,1) since p(3,1) = 0; enter next x = 4.
"	1	[B]	3.0000	Complete (4,1) entry.
"	.3	[C]	3.000	Enter p(4,1); record of 3 triplets shown.
"	3	[A]	4.0000	Only positive entry in second row, x=3.
"	2	[B]	4.0000	Enter y-value for pair (3,2).
"	.2	[C]	4.0000	Enter p(3,2).
"	2	[A]	5.0000	Enter x = 2 for only positive entry in third row
"	3	[B]	5.0000	Enter y = 3
"	.2	[C]	5.0000	Complete entry with p(2,3) = 0.2
"		[RCL]07	1.0000	Check on data entry to see $\Sigma p(x,y) = 1$
Step 2a		[E]	-0.2736	Displays the value of ρ after complete compilation and storage of moments.
Step 2b		[d]	2.7000	Displays μ_X
"		[R/S]	1.0100	Displays σ_X^2
"		[R/S]	1.6000	Displays μ_Y

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
"		[R/S]	0.6400	Displays σ_Y^2.
		[R/S]	-0.2200	Displays σ_{XY}.
		[R/S]	-0.2736	Verifies again that ρ = -0.27.

(2) Calculate the mean and the variance for g(X,Y) = XY. Verify that σ_{XY} = -0.22

Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
Step 3a		[GTO]	GTO __	Preparing for entry to subroutine
		[ALPHA]	GTO _	in order to program g(x,y) with
		[a]	GTO a_	$x \varepsilon R_{09}$, $y \varepsilon R_{10}$
		[ALPHA]	x.xxxx	
Step 3b		[PRGM]	147 LBL a	Enters program mode
"		[RCL]	148 RCL __	
		09	148 RCL 09	
"		[RCL]	149 RCL__	
"		10	149 RCL 10	
"		[x]	150 *	Completes formula z = xy
"		[RTN]	151 RTN	Required return statement for subroutine.
Step 3d		[PRGM]	x.xxxx	Return to keyboard operation (ignc display).
Step 3e		[D]	4.1000	Calculates and displays E(XY).
"		[x<>y]	3.2900	Retrieves σ^2 from R_{07} to R_X.
"		[x<>y]	4.1000	Returns E(XY) to R_X.
"		[RCL]	RCL ___	Prepares to subtract $\mu_X\mu_Y$ to
"		11	2.7000	evaluate Eq. (5-4)
		[RCL]		
"		13	1.6000	Recovers μ_Y and multiplies by μ_X
"		[x]	4.3200	
"		-	-0.2200	Calculation complete and s_{XY} verifi
Step 3f		[GTO]	GTO__	Prepare to erase algorithm in a.
		[ALPHA]	GTO_	Sends pointer to subroutine a.
		[a]	GTO a_	
		[ALPHA]	x.xxxx	
		[PRGM]	147 LBL a	Enters program mode.
		[SST]	148 yyy	Forward one step to beginning of algorithm.
		[g]	DEL ___	Execute delete function.
	010		147 LBL a	Use 10 lines (more than enough)
		[PRGM]	x.xxxx	Exit program mode. Return to calcu control.
		[e]	0.0000	Erases program.

Section 1.3: The Calculator

This section is quite like that of ZP so that only remarks concerning the statistics module need be added here. As mentioned in the introduction, the HP module STAT PAC will be needed for some of the ZS programs. In addition, the program ZSTAT, found in the appendix, will be needed for all of the ZS programs starting in Chapter 4 since they contain the probability distributions, among other things, that are missing in STAT PAC. Most of the applications of ZSTAT occur internally within ZS programs but, occasionally, some of the subroutines are called for individually. For that reason, suggestive alphanumeric labels have been included and the program has been assigned to label [SCI] to make it convenient to access from the keyboard.

Section 2.3: Simulation

The first departure from the TI format occurs on page 16 in the digression for computing moments of discrete distributions. A subroutine called MU-SIG and assigned to label [j] has been inserted into program ZS-2 to replace the TI use of ST-03. As the reader can see from the User Instructions that follow, the pairs are entered in opposite (but more natural) order with x first, followed by p . Instead of a running count of the number of pairs being displayed at the end of each entry, the cumulated probabilities are shown; thus, the number 1 should be seen at the conclusion of all entries. A press of [i] will then output the mean, and sigma will be found in the Y-register. (It should be noted throughout that, as with ZP, the HP Y-register replaces the TI T-register always).

Of course, the random number generator output will differ here, just as was the case in ZP. The same HP user instructions apply here, however. Thus, the generator is initialized by pressing [I] as before and you are prompted for a seed. The subroutine RNDMU, assigned to [H], will replace the TI [D.MS] routine to output a number between 0 and 1. If you will use a seed of .49 instead of 49 in the example treated on page 18, the HP output will be .5014, with a second application yielding .2349. A second program, called RNDMAB (assigned to [h]) replaces Steps 4-6 of ST-02 to output a (continuous) random number between A and B , provided A and B are stored in registers 13 and 14, respectively. For the example, again on page 18, using A=10 and B=67, the respective values will be 16.0050, 59.2222, 16.6282 and 24.0426. Finally, the subroutine RNDMI, assigned to [g], will generate random labels. On page 19 using a seed of .21, successive presses of [g] will produce labels 45, 53, 11 and 20. That will take care of the problems for this section. The answers will differ from those published of course. Be sure to press [J] when you wish to return to the main programs in ZS-2.

Section 2.4: Simulating Continuous Distributions

In Example 2.3, if a seed of .635 is used, the successive values of u are: .5464, .1799, .9504, .6085, .7613, yielding x values of 791, 198, 3004, 938 and 1435, respectively. The program instructions at Step E5 should be modified according to the ones provided here.

Program ST-19 may be replaced entirely by using the N routine in ZS-2 with $\mu = 0$ and $\sigma = 1$. (For that matter, P(z) may be found here by entering z and pressing [XEQ] 19, to mimic the TI program). Alternatively, program ΣNORMD in STAT PAC may be used to calculate Q(z). Try z = 2.695 as on page 24

to see that .9964 is the value of P(z). The value Q(z) = .0036 will then be found in the Y-register. Generating random samples from both the exponential and normal distributions has been automated in ZS-2 just as in the TI case and examples follow the user instructions. No further checks will be given here.

Section 2.5: Bernoulli Trials

As with ST-19, we have mimicked the TI binomial program ST-20 as subroutine 20 here. The instructions are given under the code BIN in ZS-2 and that program may be used to check all of the problems of this section. It might be noted that the standard deviation is found in the Y-register, pressing [X<>Y] after [a], rather than a separate label [B'], as with TI.

ZS-2 (Assigned [J])	USER INSTRUCTIONS (HP)			SIZE $\geq$ 030 Σ REG 01
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
E	Exponential Distribution			
1.	Initialization		[J]	0.0000
2.	Enter Parameter	λ	[STO]16	λ
3.	Compute P(x) and Q(x)	x	[E]	P(x)
	Note: λx must not exceed 228		[X<>Y]	Q(x)
4.	Calculate 100(1-α)th Percentile	α	[e]	x_α
	Note: Repeat E_3 and E_4 at will.			
5.	Generate sample of size n			
	a. Initialize Random Number Generator		[I]	SEED?
	b. Enter Seed (0 $\leq$ Seed < 1)	Seed	[R/S]	Seed
	c. Execute Step E2			
	d. Generate x (Repeat n times)		[B]	x
N	Normal Distribution			
1.	Initialization		[J]	0.0000
2.	Enter Parameters	μ	[STO]17	μ
		σ	[STO]18	σ
3.	Compute P(x) and Q(x)	x	[C]	P(x)
			[X<>Y]	Q(x)
4.	Compute $Pr(x_1 < X < x_2)$ or $1-P(x_1 < X < x_2)$			
	a. Enter x_1	x_1	[D]	$Q(x_1)$
	b. Enter x_2 and compute	x_2	[R/S]	$Pr(x_1<X<x_2)$
			[X<>Y]	$Pr(X<x_1)$ + $Pr(X>x_2)$
5.	Calculate Standard 100(1-α)th Percentile	α	[c]	z_α
6.	Calculate General 100(1-α)th Percentile	α	[d]	x_α
	Note: Repeat N_3-N_6 as often as desired			
7.	Generate sample of size n			
	a. Initialize Random Number Generator		[I]	SEED?
	b. Enter Seed (0 $\leq$ Seed < 1)	Seed	[R/S]	Seed
	c. Execute Step N1			
	d. Generate x (Repeat n times)		[b]	x
8.	Standard Normal (TI ST-19)	z	[XEQ]19	P(z)
			[X<>Y]	Q(z)

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
BIN	Binomial Distribution (TI ST-20)			
1.	Initialize		[XEQ]20	PMTERS?
2.	Enter Parameters	n	[R/S]	n
		p	[R/S]	0.0000
3.	Calculate probabilities	k	[A]	p(k)
			[R↓]	P(k)
			[R↓]	Q(k)
MU-SIG	Discrete Moments			
1.	Initialize		[j]	ΣBSTG
2.	Enter discrete pairs (Repeat i=1,...,N)	x_i	[ENTER]	x_i
		p_i	[A]	Σp_i
3.	Calculate μ and σ .		[i]	μ
			[X<>Y]	σ
MOM	Recall Moments		[a]	μ
			[X<>Y]	σ

Register Contents

00	Used	10	K(label)	20	$z = (x-\mu)/\sigma$
01	Used by Σ^+ (01–05)	11		21	n
02		12		22	p
03		13	A	23	1-p
04		14	B	24	Used
05		15		25	Used
06		16	λ	26	
07	P(x)	17	μ	27	
08	$P(x_1) - P(x_2)$	18	σ	28	
09	Seed	19	z_α	29	

Assignments	
ZS-2	J
GEN-INI	I
RNDMU	H
RNDMAB	h
RNDMI	g
BSTG	j
MU-SIG	i
XBAR	P→R
SD	R→P
RD	R↓

Labels Used		
03	A	a
06	B	b
07	C	c
08	D	d
09	E	e
11		
12		
19		
20		

EXAMPLES ZS-2.

1. Let X have an exponential distribution with parameter $\lambda = 0.001$ and suppose X measures time to failure in hours.
   (a) Calculate the probability that time to failure will exceed 1200 hours.
   (b) Compare the mean time to failure with the median time to failure.
   (c) How many hours may we reasonably depend upon for survival of 90% of such items?
   (d) Generate a random sample of five times to failure.

SOLUTIONS:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
E1		[J]	0.0000	Initialize the exponential subrout
E2	0.001	[STO]16	0.0010	Single parameter λ stored in R_{16}
E3	1200	[E]	0.6988	Displays P(1200) = Pr(X $\leq$ 1200).
		[X<>Y]	0.3012	Displays Q(1200) = Pr(X $\geq$ 1200) which is the answer to (a).
E4	.50	[e]	693.1472	Calculates and displays the median $x_{.50}$ (in hours).
		[RCL]17	1000.0000	Recall μ, the mean time to failure This answers (b).
E4	.10	[e]	105.3605	Displays x.90
E5a		[I]	SEED?	Initialize the random no. generato
E5b	.635	[R/S]	0.6350	Enter Seed = 635 for illustrative purposes.
E5c	(0.001)	([STO]16)	(0.001)	Enter the parameter λ if not already entered.
E5d		[B]	790	Displays the first generated sampl value, x_1 (rounded).
		[B]	198	The second simulated time to failu
		[B]	3003	Successive times to failure
		[B]	938	(rounded to whole hours)
		[B]	1432	for a random sample of size 5.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS

(2) A standardized test is administered to incoming freshmen at a university. Scores, X, are assumed to be normally distributed and, based on thousands of past scores, it is assumed that 1 = 100 and σ = 16. For an incoming freshman chosen at random what is the probability that the test score will be:

a) greater than 110? b) less than 90? c) between 75 and 125?

If only the top 80% of incoming freshmen are to be admitted on the basis of this test, what would the minimum passing score be?

Solutions:

N1		[J]	0.0000	Initialize.
N2	100	[STO]17	100.0000	Enter the mean value.
"	16	[STO]18	16.0000	Enter the second parameter σ.
N3	110	[C]	0.7340	Displays P(110) = Pr(X < 110).
		[X<>Y]	0.2660	Displays Q(110), the required probability.
		[RCL]20	0.6250	Shows the standardized value for x = 110, namely, z = (110-100)/16.
N3	90	[C]	0.2660	Displays P(90).
N4a	75	[D]	0.9409	Displays Q(75), of minor interest.
N4b	125	[R/S]	0.8818	Calculates and displays Pr(75<X<125).
		[X<>Y]	0.1182	Displays Pr(X<75) + Pr(X>125).
N6	.80	[d]	86.5367	Displays the 20th percentile for X, so that Pr(X>87) = 0.80.

(3) Generate a random sample of size 5 from a normal distribution

N7a		[I]	SEED?	Initialize random number generator.
N7b	.198	[R/S]	0.1980	Enter Seed = 198 for illustrative purposes
N7c	50	[STO]17	50.0000	Enter the normal parameters
	10	[STO]18	10.0000	and store in appropriate registers.
N7d		[b]	42.63	Displays first generated sample value x_1 (rounded).
		[b]	56.34	Successive sample values
		[b]	63.21	are generated and
		[b]	72.72	displayed (rounded).
		[b]	46.84	

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS

(4) Find the mean and standard deviation of the discrete probability distribution.

x:	4.0	3.0	2.0	1.0	0.0
p(x):	0.13	0.21	0.43	0.14	0.09

SOLUTION:

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
MU-SIG 1.		[j]	ΣBSTG	Initialize module to start program
MU-SIG 2.	4	[ENTER]	4.00	Enter distribution as data
	.13	[A]	0.13	pairs(x_i,p_i) i = 1,2,...,n.
	3	[ENTER]	3.00	See Σp_i accumulated in R_X with
	.21	[A]	0.34	1 indicating final data entry.
	2	[ENTER]	2.00	
	.43	[A]	0.77	
	1	[ENTER]	1.00	
	.14	[A]	0.91	
	0	[ENTER]	0.00	
	.09	[A]	1.00	
MU-SIG 3.		[i]	2.1500	Displays μ.
		[X<>Y]	1.0989	Displays σ from R_Y.

---

(5) Example 2-7.

SOLUTION:

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
BIN 1.		[XEQ]20	PMTERS?	Initialize binomial program. Prompt is for n and p.
BIN 2.	4	[R/S]	4.0000	
	.51	[R/S]	0.0000	Parameter entry complete.
BIN 3.	0	[A]	0.0576	Display P = p(0) = Pr(Y=0).
"	2	[A]	0.3747	Display is p(2) so P(2) is found
		[R↓]	0.6724	in R_Y.
		[R↓]	0.3267	Q(2) is found in R_Z.
"	1	[A]	0.2400	p(1) is displayed.
MOM		[a]	2.0400	Displays μ = np
		[X<>Y]	0.9998	Displays σ = npq
		[USER][x^2]	0.9996	Calculates σ^2.

Chapter 3 Data Processing

This chapter is rather independent of the others and, as the name suggests, deals with the processing of numerical data to produce traditional statistical summaries as well as grouping data into different patterns. Three programs have been created for this purpose, ZS-3 and two separate ones that are revisions of corresponding TI programs ST-03, ST-07 and ST-09. The latter were created and so named in order to follow the textbook material with the least amount of revision of instructions. The three programs should be loaded simultaneously for solving the problems here. Since some partitioning (using the SIZE function) may be called for, it is advisable that all other programs be cleared from calculator memory. The labels to which the programs have been assigned make it very convenient to move from one to the other when necessary.

Section 3.1: Sample Characteristics

Picking up the discussion on page 41, the HP, like the TI, is hard wired to compute means and standard deviations when data are entered on the keyboard with the $\Sigma +$ key. Consult the Owner's Handbook for details. The basic differences are that (be sure you are not in USER mode) the registers are cleared with the CLΣ key rather than using Pgm 01 and you execute the functions MEAN and SDEV instead of [$\bar{x}$] and [INV][$\bar{x}$], respectively. Even so, the TI program ST-03, here assigned to [I], will allow for data storage as it does in the TI module. You see from the User Instructions that follow, you must initialize by pressing [e] and then enter the data one-by-one using label [A]. At the conclusion you will find the data stored beginning in register 31. In addition, you may press [P→R] in place of TI [$\bar{x}$] and use [R→P] instead of TI [INV][$\bar{x}$]. To find the range, press [J] to enter program ZS-03 and then press [C] as per the instructions for that program. (Do not forget to press [I] again if you wish to return to ST-03 for any reason.) The remarks regarding repartioning may be easily transferred to appropriate remarks using the SIZE function for the HP. When data have been entered using program ST-03, you may find MSD by pressing [ENG] (the key that the subroutine MSD has been assigned to). MAD is computed by pressing [J] to enter ZS-03 and then press [B]. In this way, these instructions practically follow those of the TI to the letter. Verify the solution on page 47 for Example 3.1 following these instructions.

Section 3.2: Grouping Data

Data are grouped and recovered in cells suitable for histogram construction by means of program ST-07/9 (assigned to label [i]), a program resembling the corresponding TI programs ST-07 and ST-09 discussed in the book. The same remarks regarding conventions and parameter limitations discussed on pages 52 and 53 apply here as well.

After pressing [i] to enter the program, you initialize with [e] just as with the TI program, only here you will be prompted for the number of cells. When you enter that number with a press of [R/S] you will then be prompted for lowest class limit XMIN and, after entering that, for the width, w, of each cell. These instructions conform to the TI instructions. At this point you have two options. If data have been entered previously, either with program ST-03 or with ST-07 itself, you have merely to press [d] whereupon you are prompted for the sample size n. Entering this number and pressing [R/S] causes the program to automatically group the data into cells as per the entry

in steps P1,2,3. Otherwise, you enter the data one-by-one using [A] just as with ST-03. Once the data have been entered, the histogram is constructed by the steps under code H. After initializing with [E], the successive cell frequencies and boundaries are displayed with a STOP at the end to signal completion of the display. This replaces the discussion on pages 53 and 54 of the text.

As for computing grouped moments, the version of ST-03 presented here is initialized the same way ([e]), and pairs are entered as discussed under code G (same as the TI entry). Moments are then displayed in the X-register when XBAR ([P→R]), SD(R→P]) and MSD ([ENG]) are used. You may then proceed to ZS-3 to find MAD and the range as discussed on page 55. The last two paragraphs on that page may be safely ignored.

Section 3.3: Transformations

Step 5 of ZS-3 presented here allows for data transformations just as with the TI version. As with ZP programs, it may be advisable now and then to erase some of the algorithms used in [a] to create transformations if many applications happen to be used. Again, the DEL function will have to be used and this should be assigned to [g] if many such erasures will be taking place. You may also have to repartition your calculator with the SIZE function if there is no room for the data. For the small data sets illustrated here, that situation is not likely to arise. The answers to the problems given at the end of the section may all be verified with the program instructions on the following page.

Section 3.4: The Central Limit Theorem

The program ΣNORMD in STAT PAC will have to be used in this section in place of ST-19, or, as remarked on page 63, you may use ZS-2 with the caution mentioned there. Since there is no binomial program in STAT PAC, the latter might be the advisable thing to do for resolving some of the problems in this section.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Calculate the range of a sample when raw data have been entered using ST-03		[C]	R
2.	Calculate the range of a sample when data are grouped and have been entered using ST-03 (w = cell width).	w	[c]	R
3.	Compute MAD when ungrouped data have been entered using ST-03.		[B]	MAD
4.	Compute MAD when grouped data have been entered using ST-03		[b]	MAD
5.	Transform data by the transformation x' = f(x):			
	a. Initialization.		[e]	0.0000
	b. Enter program mode		[GTO][a]	x.xxxx
			[PRGM]	160 LBL a
	c. Enter f(x) using parentheses where necessary and always end with [INV][SBR]. Exit program mode.		. . [PRGM]	x.xxxx
	d. (1) Keyboard Entry (repeat for each i).	x_i	[A]	i.0000
	(2) Original Data Stored by ST-03 (n = sample size).	n	[E]	n.0000
	NOTE 1: Steps 1 and 3 apply following Step 5d.			
	† NOTE 2: To ERASE Algorithm in [a], complete Step b; then... (Let nnn be at least as large as the number of steps in [a])	[XEQ][DEL]†	[SST] [g] nnn [PRGM]	161 yy DEL___ 161 LBL a x.xxxx
6.	Recall transformed data.		[d]	0.0000
			[D]	x'_1
	NOTE: May be repeated at any time.		[D]	x'_2
			[D]	x'_3
			⋮	⋮
7.	Clear Step 6		[CF]01	x.xxxx

†For repeated applications of Step 5, use ASN to assign the function DEL to label g(%) before executing this step. (DEL is not programmable and cannot be preserved in user code by the card reader.)

ST-03 (Assigned [I])	USER INSTRUCTIONS (HP)			SIZE 060-089 Σ REG 01
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
I	Initialization		[e]	0.0000
U	Ungrouped Data Entry Repeat $i = 1,2,\ldots,n$.	x_i	[A]	i.0000
G	Grouped Data Entry Repeat $i = 1,2,\ldots,n$.	f_i x_i	[B] [A]	f_i i.0000
MOM	1. Calculate sample mean and sample Standard Deviation 2. Calculate MSD		[P→R] [R→P] [ENG]	$\bar{x}$ MSD

REGISTER CONTENTS (Grouped data in parentheses)

00	Used	10	$1(f_i)$	20	30	Pointer
01	$\Sigma x(\Sigma fx)$	11	w	21	31	$x_1(x_1)$
02	$\Sigma x^2(\Sigma fx^2)$	12	x_{min}	22	32	$x_2(f_1)$
03		13	x_{max}	23	33	$x_3(x_2)$
04		14	Used	24	34	$x_4(f_2)$
05		15		25	35	.
06	$n(\Sigma f_i)$	16		26	36	⋮
07	$\Sigma\lvert x_i-\bar{x}\rvert$	17		27	37	
08	Used	18	Used	28	38	
09	Lastx	19	xcount	29	39	

Assignments

ZS-3	J
ST-03	I
ST-07/9	i
XBAR	P→R
SD	R→P
MSD	ENG

Labels Used

ZS-3			ST-03			ST-07/9		
01	A	a	01	A	e	01	A	c
02	B	b	02	B		02	E	d
03	C	c	03			03		e
04	D	d				04		
05	E	e						
12								
13								

ST-07/9 (Assigned [i]) USER INSTRUCTIONS SIZE 060-089

Σ REG 01

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
I	Initialization		[i]	0.0000
P	Enter Parameters		[e]	CELLS?
1.	Enter number of cells ($\leq$ 15)	Cells	[R/S]	XMIN?
2.	Enter Lowest Class Limit	x_{min}	[R/S]	W = ?
3.	Enter Interval Width	w	[R/S]	0.0000
DE	Data Entry and Compilation			
1.	Original Data (Repeat i = 1,2,...,n) OR:	x_i	[A]	i.0000
2.	If Data Are Previously Stored		[d]	N = ?
		n	[R/S]	n.0000
H	Histogram Construction (after DE)			
1.	Initialization		[E]	0.0000
2.	Display Cell Frequency		[c]	f_i
3.	Display Upper Limit, B_i, of Interval		[R/S]	B_i
	(Repeat i = 1,2,...,Cells)		⋮	⋮ STOP
	<u>Note</u>: Ungrouped moments after DE may be computed by XBAR, SD and MSD in ZS-3. Corresponding grouped moments are then found in R_Y if Histogram has been constructed. In either case, you must press [i] again to return to ST-07/9.			

<u>REGISTER CONTENTS</u>

00	Used	10	Used	20	f_7	30	Pointer
01	Σx_i	11	w	21	f_8	31	x_1
02	Σx_i^2	12	x_{min}	22	f_9	32	x_2
03	$\Sigma f_i x_i$	13	x_{max}	23	f_{10}	33	x_3
04	$\Sigma f_i x_i^2$	14	f_1	24	f_{11}	34	⋮
05	Used	15	f_2	25	f_{12}	35	
06	n	16	f_3	26	f_{13}	36	
07	Used	17	f_4	27	f_{14}	37	
08	Used	18	f_5	28	f_{15}	38	
09	CELLS	19	f_6	29	xcount	39	

EXAMPLES ZS-3

1. For the ungrouped data below, calculate $\bar{x}$, s, MSD, MAD and R. Then transform the data by x' = 1/x and calculate the same statistics for the transformed data.

5, 10, 6, 4, 3, 8, 12

Recall the actual values of the first three data points.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
ST-03		[I]	0.0000	Select ST-03
I		[e]	0.0000	Initialize for data entry.
U	5	[A]	1.0000	Enter data.
	10	[A]	2.0000	
	6	[A]	3.0000	
	4	[A]	4.0000	
	3	[A]	5.0000	
	8	[A]	6.0000	
	12	[A]	7.0000	Data Entry complete.
		[P→R]	6.8571	The value of the sample mean.
		[R→P]	3.2878	The value of the sample standard deviation.
		[ENG]	9.2653	Value of MSD.
ZS-3		[J]	9.2653	Enter program ZS-03.
3.		[B]	2.6939	MAD calculated and displayed.
1.		[C]	9.0000	The range R = 9
5a.		[e]	0.0000	Initialize ZS-3 for data transformation.
5b.		[GTO][a][PRGM]	160 LBLa	Preparation for transformation.
5c.		[1/x]	161 1/x	Simple algorithm.
"		[RTN]	162 RTN	Necessary return instruction.
"		[PRGM]	x.xxxx	Exit program mode for ZS-3 operation.
5d.(2)	7	[E]	7.0000	Data automatically transformed an stored in R_{31}, R_{32}, ...
		[P→R]	0.1798	Value of $\bar{x}$' rounded.
		[R→P]	0.0892	Rounded value of s'.
		[ENG]	0.0068	Rounded value of MSD'.
3.		[B]	0.0697	Rounded value of MAD'.
1.		[C]	0.2500	Value of R', the new range.
6.		[d]	0.0000	Initialize to recall transformed data.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
		[D]	0.2000	Recall value of $x'_1 = 1/x_1$.
		[D]	0.10000	Recall value of $x'_2 = 1/x_2$.
		[D]	0.1667	Recall value of $x'_3 = 1/x_3$.
		[CF]01	0.1667	Clear display program

2. For the grouped data below, calculate $\bar{x}$, s, MSD, MAD and the range.

Frequency:	3	4	9	4	5
Class Interval:	0-10	10-20	20-30	30-40	40-50

SOLUTION:

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
ST-03		[I]	0.0000	Select program ST-03.
I		[e]	0.0000	Initialize ST-03 for data entry.
G	3	[B]	3.0000	Enter first frequency.
	5	[A]	1.0000	Enter first midpoint; running count
	4	[B]	4.0000	displayed.
	15	[A]	2.0000	Repeat for each pair.
	9	[B]	9.0000	
	25	[A]	3.0000	
	4	[B]	4.0000	
	35	[A]	4.0000	
	5	[B]	5.0000	
	45	[A]	5.0000	Data entry concluded.
		[P→R]	26.6000	Grouped mean value $\bar{x}$.
		[R→P]	12.8062	Rounded value of s.
		[ENG]	157.4400	Value of MSD.
ZS-3		[J]	157.4400	Enter Program ZS-3
4.		[b]	10.0480	Value of MAD.
2.	10	[c]	50.0000	Value of grouped range R-based on a class width of 10.

3. Group the following data into a histogram consisting of 6 cells of width w = 10 starting at $x_{min} = 70$.

120	86	87	75	100	120	100	80
110	105	95	90	100	85	95	85

Calculate: $\bar{x}$, s, MSD for both grouped and ungrouped data.

SOLUTION:

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
ST-07/9		[i]	0.0000	Select program ST-07-9
I		[e]	CELLS?	Initialize for parameter entry.
P1	6	[R/S]	XMIN?	Enter total number of cells.
P2	70	[R/S]	W = ?	Enter x_{min}, lowest data limit.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
P3	10	[R/S]	0.0000	Enter cell width.
DE	120	[A]	1.0000	Enter first data value
	86	[A]	2.0000	Enter second data value
		⋮	⋮	⋮
	85	[A]	16.0000	Enter last data value
H1		[E]	0.0000	Initialize histogram display.
H2		[c]	1	First cell frequency
H3		[R/S]	80.0000	B_1 so Cell 1 runs from 70 to 80.
H2		[c]	5	Second cell frequency
H3		[R/S]	90.0000	B_2 establishing interval 80 to 90
H2		[c]	3	Third cell frequency
H3		[R/S]	100.0000	Third cell upper limit.
H2		[c]	4	Fourth cell frequency
H3		[R/S]	110.0000	Fourth cell boundary.
H2		[c]	1	Fifth frequency for cell
H3		[R/S]	120.0000	running from 110 to 120
H2		[c]	2	Sixth frequency for last cell.
H3		[R/S]	130.0000	Upper bound on all data (not included as a possible value)
		[c]	STOP	Indicates conclusion of program.
		[P→R]	95.8125	$\bar{x}$ for ungrouped data
		[X<>Y]	98.1250	$\bar{x}$ for grouped data
		[R→P]	13.2525	s for ungrouped data
		[X<>Y]	14.9304	s for grouped data
		[ENG]	164.6523	MSD for ungrouped data
		[X<>Y]	208.9844	MSD for grouped data
		[i]	0.0000	Ensures return to ST-07/9

Chapter 4 Estimation

Chapter 5 Hypothesis Testing

The problems in both of these chapters are covered by a single program, called ZS-4/5. This was one of the more successful translations from TI to HP so that very little needs to be added in the way of remarks. As the reader will see from the User Instructions that follow, the directions are practically identical to those published in the text. One small difference is that raw data will not be entered by ST-03, but rather by a self-contained data entry scheme (DE) which is much simpler and covers all of the cases treated. Naturally, any TI reference to the T-register should be translated to the HP Y-register, and the display register, R_D referred to so often, becomes the HP X-register. Another important point that is universally true of the difference between the two calculators is that R_{06} is used by the HP routines for storing sample sizes while TI used R_{03}. That change should be noted throughout the instructions that follow.

As previously remarked, the program ZSTAT should be loaded into program memory for all of the ZS programs from this point on in the text. It will be convenient to assign ZSTAT to a label, say [SCI], for easy access to the programs that are referred to occasionally in these chapters.

On page 85 reference is made to the formula for the t-density in ASM. It is really not particularly instructive for the applications presented here to actually see the formula but it may be found in most standard textbooks, and a picture of the typical density is shown on page 103. In any case the value of the CDF P(t) may be found by storing degrees of freedom, ν , in R_{15}, entering t and then [XEQ][TF] in ZSTAT. On page 86 it should be noted that the subroutine ZA in ZSTAT replaces the subroutine [sin] in TI. (See also the Note in the User Instructions that follow.)

One of the few distributions provided by STAT PAC is the Chi-square, referred to on page 92. This distribution is labeled ΣCHISOD and is discussed on page 70 of the STAT PAC handbook. It may also be found as the subroutine [CHISD] in ZSTAT (requiring, again, only that degrees of freedom be store in R_{15}). Either replaces references to [C] in TI ST-21. A typical Chi-square density is depicted in the legend to Table C on page 104, where percentiles are located. It should be observed that the footnote regarding large degrees of freedom applies verbatim to the HP program ZS-4/5.

That takes care of all of the differences in these two chapters. Following the User Instructions on the next three pages will be found the typical model problems for verifying program output.

ZS-4/5 Assigned [J]) USER INSTRUCTIONS (HP) SIZE 050

Σ REG 01

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
DE	ORIGINAL DATA ENTRY			
1.	Enter Data			
	a. Initialize		[J]	DATA?
	b. x_i Repeat i = 1,2,...,n		[R/S]	i.0000
2.	Process Data for Storage		[d]	0.0000
N(μ)	NORMAL MEAN - σ UNKNOWN			
1.	Enter Data using DE OR:			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Sample Mean	$\bar{x}$	[STO]37	$\bar{x}$
	c. Enter Sample Standard Deviation	s	[STO]38	s
2.	Test $H_0 : \mu = \mu_0$			
	a. Enter H_1-code*	H_1-code	[a]	H_1-code
	b. Enter μ_0 and Compute P-value	μ_0	[R/S]	P
3.	CI for μ			
	a. Calculate Degrees of Freedom		[A]	ν
	b. Enter $t_{\alpha/2}$ with d.f. = ν	$t_{\alpha/2}$	[R/S]	ℓ
	and calculate limits		[X<>Y]	u
	NOTE: For One-sided intervals, enter t_α at Step 3b and ignore ℓ or u as the case may be.			
N($\mu\|\sigma$)	NORMAL MEAN - σ KNOWN			
1.	Enter Data Using DE OR:			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Sample Mean	$\bar{x}$	[STO]37	$\bar{x}$
3.	Test $H_0 : \mu = \mu_0$			
	a. Enter H_1-Code	H_1-code	[b]	H_1-code
	b. Enter μ_0 and Compute P-value	μ_0	[R/S]	P
4.	Calculate 100(1-α)% CI for μ	$\alpha/2$	[B]	ℓ
			[X<>Y]	u
	Note: Enter α for one-sided intervals and ignore ℓ or u as the case may be.			

$$
^{*}\; H_1\text{-code} = \begin{cases} 1 & \text{if } H_1 : \theta > \theta_0 \\ 0 & \text{if } H_1 : \theta \neq \theta_0 \\ -1 & \text{if } H_1 : \theta < \theta_0 \end{cases}
$$

Note: In ZSTAT (assigned [SCI]), [XEQ][ZA] displays z_P if P is in R_X

S-4/5	USER INSTRUCTIONS			
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
N(σ^2)	NORMAL VARIANCE			
1.	Enter Data Using DE OR:			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Sample Standard Deviation	s	[STO]38	s
2.	Test $H_0 : s^2 = \sigma_0^2$			
	a. Enter H_1-code	H_1-code	[c]	H_1-code
	b. Enter σ_0^2 and Compute P-value	σ_0^2	[R/S]	P
3.	CI for σ^2			
	a. Calculate Degrees of Freedom		[C]	ν
	b. Enter Chi-square Percentiles	$\chi^2_{1-\alpha/2}$	[STO]41	$\chi^2_{1-\alpha/2}$
	(ν=n-1) and Calculate Limits	$\chi^2_{\alpha/2}$	[STO]31	$\chi^2_{\alpha/2}$
			[R/S]	ℓ
			[X<>Y]	u
	NOTE: For Upper One-sided Interval, enter $\chi^2_{1-\alpha}$ in R_{41} and in R_{31} and see u displayed. For Lower One-sided interval, enter χ^2_{α} in R_{31} and R_{41} see see ℓ displayed.			
Exp(μ)	Exponential Mean			
1.	Enter data using DE or:			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Sample Mean	$\bar{x}$	[STO]37	$\bar{x}$
2.	Test $H_0 : \mu = \mu_0$			
	a. Enter H_1-code	H_1-code	[e]	H_1-code
	b. Enter μ_0 and Compute P-value	μ_0	[R/S]	P
3.	CI for			
	a. Calculate Degrees of Freedom		[E]	ν
	b. Enter Chi-square Percentile ν=2n	$\chi^2_{1-\alpha/2}$	[STO]41	$\chi^2_{1-\alpha/2}$
	and Calculate Limits	$\chi^2_{\alpha/2}$	[STO]31	$\chi^2_{\alpha/2}$
			[R/S]	ℓ
			[X<>Y]	u
	NOTE: See Previous Note for One-Sided Intervals.			

REGISTER CONTENTS

00		10		20		30	ts	40	θ
01	Σx_i	11		21		31	$t_{\alpha/2}$, $\chi^2_{\alpha/2}$	41	$\chi^2_{1-\alpha/2}$
02	Σx_i^2	12		22		32	SE	42	
03		13		23		33	Used	43	
04		14	Used	24		34	θ_0	44	
05	Used	15	ν	25		35		45	
06	n	16		26	Used	36		46	
07		17		27		37	$\bar{x}$	47	
08		18		28	H_1-code	38	s	48	
09		19		29	P(ts)	39	e($\theta\pm$e)	49	Used

Assignments

ZS-4/5 | J

Labels Used

01	A	a
02	B	b
03	C	c
04	D	d
05	E	e
06		
07		

EXAMPLES ZS-4/5

(1) To study the effects of a drug, nine athletes were timed in a series of physical tests and yielded an average of $\bar{x}$ = 10.13 minutes. It was assumed in the study that σ = 1 and that reaction times are normally distributed.

a. Find a 90% CI for the mean reaction time μ.

b. Determine a 99% lower one-sided interval for μ.

c. Find a one-sided upper bound on μ having risk 15%.

(2) Four specimens of an expensive cloth were subjected to strength tests and the breaking strengths in lbs./sq. in. were recorded as 181, 173, 176, 175. The standard deviation based on past experience is 5 lbs./sq in. Assume normality.

a. Find a 95% CI for μ, the mean breaking strength.

b. What is a lower one-sided bound for μ with confidence 90%?

Solution (1):

ZP STEP		ENTER	PRESS	DISPLAY	COMMENTS
N(μ|σ)	1a.	9	[STO]06	9.0000	Places the sample size in R_{06}.
	1b.	10.13	[STO]37	10.1300	Stores the sample average in R_{37}.
	2.	1	[STO]48	1.000	Stores known σ-value in R_{48}.
	4.	.05	[B]	9.5816	Enter $\alpha/2$ = .10/2; display ℓ.
			[X<>Y]	10.6784	Exchange and display u. 90% CI for μ is (9.58, 10.68).
	4.	.01	[B]	9.3544	Enter α = .01 and find ℓ = 9.35 so confidence is 99% that μ > 9.35 solving (b) (R_Y is not examined)
	4.	.15	[B]	9.78	Using α = .15, ℓ is calculated but ignored.
			[X<>Y]	10.4755	The Y-register yields required upper limit on μ, solving (c).

Solution (2):

DE	1.		[J]	DATA?	
			[R/S]	0.0000	Initialize ZS-4 for data entry.
		181	[R/S]	1.0000	First breaking strength entered.
		173	[R/S]	2.0000	Second breaking strength entered.
		176	[R/S]	3.0000	Third breaking strength entered.
		175	[R/S]	4.0000	Fourth breaking strength entered.
DE	2.		[d]	0.0000	Data processed.
N(μ|σ)	2.	5	[STO]48	5.0000	Stores known σ-value in R_{48}.

ZS STEP		ENTER	PRESS	DISPLAY	COMMENTS
	4.	.025	[B]	171.3490	Entering $\alpha/2$ for α = .05, ℓ is displayed.
			[X<>Y]	181.1510	Y-register yields u. CI:(171.3,1 is reported and (a) is resolved.
	4.	.10	[B]	173.0457	The 90% lower limit for (b) of 17 is found using α = .10.

(3) Five specimens of coke tested for porosity showed weight gains of 2.16, 2.19, 2.31, 2.30 and 2.21, all in pounds. The variance of the process is unknown. Find a 90% C.I. for the mean weight gain. Find estimates of μ and σ and SE.

Solution:

DE	1.		[J]	DATA?	
			[R/S]	0.0000	Initialize ZS-4 Ungrouped for dat entry.
		2.16	[R/S]	1.0000	First weight entered.
		2.19	[R/S]	2.0000	Successive weights entered.
		2.31	[R/S]	3.0000	
		2.30	[R/S]	4.0000	
		2.21	[R/S]	5.0000	
DE	2.		[d]	0.0000	Process data.
N(μ)	3a.		[A]	4.0000	Display ν = 4.
	3b.	2.132	[R/S]	2.1698	Lower confidence limit displayed
			[X<>Y]	2.2982	Upper Limit retrieved from R_Y.
			[RCL]40	2.2340	Retrieve $\hat{\mu} = \bar{x}$, the estimate of μ.
			[RCL]38	0.0673	Retrieve $\hat{\sigma}$, the estimate of σ.
			[RCL]32	0.0301	Retrieve $s/\sqrt{n}$, the estimate of SE.

Report $2.17 < \mu < 2.30$ or 90% C.I. for μ is (2.17, 2.30).

(4) Summary data for a problem are $\bar{x}$ = 2.268 and s = 0.225. Determine a 90% lower one-sided C.I. for μ and an upper 99% C.I. for μ.

Solution:

N(μ)	1a.	5	[STO]06	5.0000	Enter the sample size in R_{03}.
	1b.	2.268	[STO]37	2.2680	Enter the sample average in R_{40}.
	1c.	.225	[STO]38	0.2250	Enter the sample s.d. in R_{38}.
	3a.		[A]	4.0000	Display ν = 4.
	3b.	1.533	[R/S]	2.1137	Lower limit is displayed; R_Y ignor
	3a.		[A]	4.	
	3b.	3.747	[R/S]	(1.890)	$t_{.01}$ entered and lower limit ignor
			[X<>Y]	2.6450	R_Y yields the upper one-sided limi

ZS STEP		ENTER	PRESS	DISPLAY	COMMENTS

(7) Times to failure for six expensive pieces of electronic equipment were recorded in hours as 233.6, 1402.7, 3119.0, 612.9, 258.3 and 2211.2.

(a) Find a 95% C.I. for mean time to failure.

(b) Determine a point estimate and a lower one-sided 95% confidence limit on the reliability at 500 hrs.

Solution:

ZS	STEP	ENTER	PRESS	DISPLAY	COMMENTS
DE	1.		[J]	DATA?	
			[R/S]	0.0000	Initialize ZS-4 for raw data entry.
		233.6	[R/S]	1.0000	First time to failure entered.
		1402.7	[R/S]	2.0000	Succeeding times to failure
		3119	[R/S]	3.0000	entered and processed.
		612.9	[R/S]	4.0000	
		258.3	[R/S]	5.0000	
		2211.2	[R/S]	6.0000	
DE	2.		[d]	0.0000	Data processed.
Exp(μ)	3a.		[E]	12.0000	Display $\nu = 2n$
	3b.	4.4	[STO]41	4.4	Storing lower percentile in R_{41}
		23.4	[STO]31	23.3	Storing upper percentile in R_{31}
			[R/S]	669.8889	Display ℓ
			[X<>Y]	3562.5909	Find u so CI is (673,3563)
			[RCL]40	1306.2833	$\hat{\mu} = \bar{x} = 1306$
			[U][1/x][U]	0.0008	$\hat{\lambda} = 1/\bar{x} = 0.0008$
		500	[x]	0.3828	Multiplying by 500 to find $500\hat{\lambda}$
			[CHS]	-0.3828	Change sign for exponentiation
			[U][e^x][U]	0.6820	to yield estimate of R(500).
			[E]	12.0000	Display ν to start new problem.
		21.0	[STO]31	21.0000	Store required $\chi^2_{.05}$ in R_{31}
			[STO]41	1.0000	and 1 in R_{41} for one-sided limit.
			[R/S]	746.4476	Display required lower limit on μ
			[U][1/x][U]	0.0013	Upper limit on λ
		500	[x]	0.6698	Multiplying by 500 to find upper limit on -500λ
			[CHS]	-0.6698	Lower limit on -500λ
			[U][e^x][U]	0.5118	Lower bound on R(500).

NOTE: [U] stands for the [USER] key.

Examples ZS-4 (Testing, Chapter 5)

(1) Seven observations of measured radiation intensity at a nuclear plant we 3.6, 4.2, 4.0, 4.1, 3.8, 3.9, 4.0. Conduct a significance test of $H_0 : \mu \leq 3.8$ against $H_1 : \mu > 3.8$.

Solution:

ZS STEP		ENTER	PRESS	DISPLAY	COMMENTS
DE	1		[J]	DATA?	Select and initialize ZS-4
		3.6	[R/S]	1.0000	
		4.2	[R/S]	2.0000	
		⋮			Enter Data
		4.0	[R/S]	7.0000	
DE	2		[d]	0.0000	Process data.
N(μ)	2a.	1	[a]	1.0000	Enter H_1-code (+1).
	2b.	3.8	[R/S]	0.0530	Enter boundary value and compute P = .053 from t-density.

---

(2) A water meter has variance 14 (cu. ft)^2. Twenty monthly readings indicat a sample mean of 1284 cu. ft. per month.

(a) Test the hypothesis $H_0 : \mu = 1286$ against $H_1 : \mu \neq 1286$, using $\alpha = .05$.

(b) Calculate the significance level for the one sided alternative $H_1' : \mu < 1286$.

Solution:

N(μ|σ)1a	20	[STO]06	20.0000	Enter sample size.
N(μ|σ)1b	1284	[STO]37	1284.0000	Enter sample average.
N(μ|σ)1c	14	[$\sqrt{x}$][STO]48	3.7417	Enter known σ.
N(μ|σ)4	.025	[B]	1284.3598	ℓ
		[X<>Y]	1285.6402	u (Since (ℓ,u) does not contain μ_0, H_0 is rejected.)
N(μ|σ)3a	-1	[b]	-1.0000	H_1-code for part (b).
N(μ|σ)3b	1286	[R/S]	0.0084	P-value (data are inconsistent with H_0).

ZS STEP		ENTER	PRESS	DISPLAY	COMMENTS

(3) The standard deviation in GRE scores nationwide has been 40 points. The GRE scores for 86 Smith High School students this year has (sample) standard deviation 35.2. What is the significance of this result?

Solution:

$N(\sigma^2)$	1a.	86	[STO]06	86.0000	Enter sample size.
$N(\sigma^2)$	1b.	35.2	[STO]38	35.2000	Enter sample standard deviation.
$N(\sigma^2)$	2a.	0	[c]	0.0000	Enter H_1-code for $H_1 : \sigma \neq 40$.
$N(\sigma^2)$	2b.	1600	[R/S]	0.1220	P-value. (Data are somewhat consistent with $H_0 : \sigma = 40$.)

---

(4) Times to failure of a sample of 12 unused D-cells were (in weeks): 27, 41, 29, 33, 30, 33, 26, 37, 29, 11, 20, 29. The shelf life is claimed to be at least 35 weeks. Conduct a significance test of $H_0 : \mu \leq 35$ vs. $H_1 : \mu > 35$.

Solution:

DE	1		[J]	DATA?	Select and initialize ZS-4.
			[R/S]	0.0000	
		27	[R/S]	1.0000	Enter data
		41	[R/S]	2.0000	
		⋮	⋮	⋮	
		29	[R/S]	12.0000	
DE	2		[d]	0.0000	Process data.
Exp(μ)	2a.	1	[e]	1.0000	Enter H_1-code
Exp(μ)		35	[R/S]	0.7129	P-value (data are consistent with H_0.)

Chapter 6 Bivariate Populations

Program ZS-6 is another very successful transfer from the TI version and is assigned to [J] which also serves to initialize data entry and will ultimately replace references to ST-04. For matters discussed in Section 6.2, however, it is more convenient to use the program ΣBSTAT in STAT PAC. The procedure for inputting paired data is discussed on page 11 of the STAT PAC handbook. Output is then displayed by successive [R/S]'s, some of which are of no interest here. It should be noted that the output labeled GXY is simply the correlation coefficient referred to on page 130 of ZS. Also, in the notation of ZS, the HP output labeled SX. is RMSD for X, while SY. is RMSD for Y.

The STAT PAC program ΣBSTAT does not appear to be suitable for entering independent data of the type discussed on page 131 of ZS. Nor is any provision made for entering univariate data in any of the programs published in STAT PAC. The simplest solution is to start with the x-data and enter the data twice at Step 2 (that is, let $y_i = x_i$) in BSTAT, in which case all of the moments are X-moments and the correlation is 1; alternatively, the [ENTER] portion of Step 2 may be ignored, each x entered with [A] in which case you should ignore all X-outputs in the list and copy only those for Y and ignore GXY altogether. Then the whole process needs to be repeated for the y-data.

Section 6.3; Paired Data

For implementation of the programs in ZS-6, raw data will be entered via a self-contained subroutine, called DE in the User Instructions that follow, and replaces references to ST-04 in the rest of the chapter. That subroutine is divided into two parts depending on whether the data are paired or independent. For this section, the data are paired so that option P will be used and the user instructions make it clear how the data are to be entered. Be sure to process the data after entry by pressing [d]. Otherwise, the instructions are identical to those provided in the book for TI.

Section 6.4: Independent Data

In this section the I option of data entry DE is to be used and, at the conclusion of data entry once more [d] must be used to process the data. Please keep in mind also that R_{06} is to be used in place of TI R_{03} throughout. The rest of the instructions are identical.

Section 6.5: Equality of Variances

No F-distribution is provided by STAT PAC so that distribution has been programmed into ZSTAT. Again, no formula is provided in ZS, nor is one really needed in this context. But the subroutine FCDF in ZSTAT will output P(F), while FCCDF will output Q(F) provided ν_1 is in R_{15} and ν_2 is in R_{16}. For example, if $\nu_1 = 2$ and $\nu_2 = 24$, you may verify by executing FCCDF in ZSTAT that $Q(2.63) = .0927$; if $\nu_1 = 20$ and $\nu_2 = 7$, then $P(.4) = .0510$. Again, the rest of the remarks in the book apply to the HP programs verbatim.

S-6 (Assigned [J])	USER INSTRUCTIONS (HP)		SIZE 050 Σ REG 01	
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
DE	ORIGINAL DATA ENTRY			
0.	Initialize		[J]	DATA?
1.	Enter Data			
	a. Paired Data		[P]	0.0000
	(Repeat i = 1,2,...,n)	x_i	[ENTER]	x_i
		y_i	[R/S]	i.0000
	b. Independent Data		[I]	0.0000
	(1) Repeat $i = 1,2,...,n_x$	x_i	[R/S]	i.0000
			[j]	0.000
	(2) Repeat $j = 1,2,...,n_y$	y_j	[R/S]	
2.	Process Data		[d]	0.0000
PN	Paired Data: $\mu_x - \mu_y$			
1.	Enter Data Using DE OR:			
	a. Enter Sample Size	n	[STO006	n
	b. Enter Sample Means			
	(1) Original Means	$\bar{x}$	[STO]47	$\bar{x}$
	OR:	$\bar{y}$	[STO]37	$\bar{y}$
	(2) Mean Difference	$\bar{d}$	[STO]47	$\bar{d}$
		0	[STO]37	0
	c. Enter Sample Standard Deviation	s_d	[STO]27	s_d
2.	Test $H_0 : \mu_x - \mu_y = \theta_0$			
	a. Enter H_1-code*	H_1-code	[b]	H_1-code
	b. Enter θ_0 and Computer P-value	θ_0	[R/S]	P
3.	CI for $\mu_x - \mu_y$			
	a. Calculate degrees of freedom		[B]	ν
	b. Enter $t_{\alpha/2}$ with d.f. = ν and Calculate Limits	$t_{\alpha/2}$	[R/S]	ℓ
			[X<>Y]	u
	Note: For one-sided intervals, enter t_α at 3b and ignore ℓ or u as the case ,may be.			

$$^*H_1\text{-code} = \begin{cases} 1 \text{ if } H_1 : \theta > \theta_0 \\ 0 \text{ if } H_1 : \theta \neq \theta_0 \\ -1 \text{ if } H_1 : \theta < \theta_0 \end{cases}$$

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
INA ($\sigma_x = \sigma_y$)	Independent Data: $\mu_x - \mu_y$			
1.	Enter data Using DE OR: Clear Memory and		[J]	DATA?
	a. Enter Sample Sizes	n_x	[STO]13	n_x
		n_y	[STO]06	n_y
	b. Enter Sample Averages	$\bar{x}$	[STO]47	$\bar{x}$
		$\bar{y}$	[STO]37	$\bar{y}$
	c. Enter Standard Deviation			
	(1) Pooled Estimate Available OR:	s_p	[STO]33	s_p
	(2) Original S.D.'s Available	s_x	[STO]48	s_x
		s_y	[STO]38	s_y
2.	Test $H_0 : \mu_x - \mu_y = \theta_0$			
	a. Enter H_1-Code	H_1-code	[c]	H_1-code
	b. Enter θ_0 and Compute P-value	θ_0	[R/S]	P
3.	CI for $\mu_x - \mu_y$			
	a. Calculate degrees of freedom		[C]	ν
	b. Enter $t_{\alpha/2}$ with d.f. = ν and Calculate Limits	$t_{\alpha/2}$	[R/S]	ℓ
			[X<>Y]	u
	See Previous Note for One-sided Limits.			
INB ($\sigma_x \neq \sigma_y$)	Independent Data: $\mu_x - \mu_y$ (Welch Approximate t)			
1.	Enter Data using DE OR:			
	a. Enter Sample Sizes	n_x	[STO]13	n_x
		n_y	[STO]06	n_y
	b. Enter Sample Means	$\bar{x}$	[STO]47	$\bar{x}$
		$\bar{y}$	[STO]37	$\bar{y}$
	c. Enter Sample Standard Deviations	s_x	[STO]48	s_x
		s_y	[STO]38	s_y

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
2.	Test $H_0 : \mu_x - \mu_y = \theta_0$			
	a. Enter H_1-code	H_1-code	[a]	H_1-code
	b. Enter θ_0 and Compute P-value	θ_0	[R/S]	P
3.	CI for $\mu_x - \mu_y$			
	a. Calculate Degrees of Freedom		[A]	ν
	b. Enter $t_{\alpha/2}$ with d.f. = ν and Calculate Limits	$t_{\alpha/2}$	[R/S]	ℓ
			[X<>Y]	u
	See Previous Note for One-Sided Limits			
LSN	LARGE SAMPLE NORMAL $\mu_x - \mu_y$			
	OR: σ_x, σ_y known			
1.	Enter Summary Data Only:			
	a. Enter Sample Sizes	n_x	[STO]13	n_x
		n_y	[STO]06	n_y
	b. Enter Sample Means	$\bar{x}$	[STO]47	$\bar{x}$
		$\bar{y}$	[STO]37	$\bar{y}$
	c. Enter Standard Deviations	σ_x or s_x	[STO]48	σ_x or s_x
		σ_y or s_y	[STO]38	σ_y or s_y
2.	Test $H_0 : \mu_x - \mu_y = \theta_0$			
	a. Enter H_1-code	H_1-code	[a]	H_1-code
	b. Set Flag 5		[SF]05	H_1-code
	c. Enter Focal and Calculate P-value	θ_0	[R/S]	P
3.	CI for $\mu_x - \mu_y$			
	a. Initialize (Ignore output)		[A]	xx
	b. Enter $z_{\alpha/2}$ and Calculate Limits	$z_{\alpha/2}$	[R/S]	ℓ
			[X<>Y]	u
	See Previous Note for One-Sided Limits			

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
NV	Independent Data σ_x^2/σ_y^2			
1.	Enter Data using DE OR:			
	a. Enter Sample Sizes	n_x	[STO]13	n_x
		n_y	[STO]06	n_y
	b. Enter Sample Standard Deviations	s_x	[STO]48	s_x
		s_y	[STO]38	s_y
2.	Test $H_0 : \sigma_x^2 = \sigma_y^2$			
	a. Enter H_1-code; Set Flag 4.	H_1-code	[SF]04	H_1-code
	b. Calculate P-value		[D]	P
3.	CI for σ_x^2/σ_y^2			
	a. Compute Degrees of Freedom		[D]	ν_1
	From Accompanying Table:		[R/S]	ν_2
	b. Enter F-value with d.f. = (ν_1,ν_2)	$F_{\alpha/2}$	[STO]31	$F_{a/2}$
	c. Enter F-value with d.f. = (ν_2,ν_1)	$F_{\alpha/2}$	[STO]41	$F_{\alpha/2}$
	d. Calculate Limits		[R/S]	ℓ
			[X<>Y]	u
	Note: a. For Lower One-Sided Interval, enter F_α at Step 3b, 1 at Step 3c and ignore u. b. For Upper One-Sided Interval, enter 1 at Step 3b, F_α at Step 3c and ignore ℓ .			
Exp	Independent Exponential μ_x/μ_y			
1.	Enter Data Using DE OR:			
	a. Enter Sample Sizes	n_x	[STO]13	n_x
		n_y	[STO]06	n_y
	b. Enter Sample Means	$\bar{x}$	[STO]47	$\bar{x}$
		$\bar{y}$	[STO]37	$\bar{y}$
2.	Test $H_0 : \mu_x = \mu_y$			
	a. Enter H_1-code; Set Flag 4.	H_1-code	[SF]04	H_1-code
	b. Calculate P-value (See Note under NV2)		[E]	P

TEP	PROCEDURE	ENTER	PRESS	DISPLAY
3.	CI for μ_x/μ_y			
	a. Compute Degrees of Freedom		[E]	ν_1
	From Accompanying Table:		[R/S]	ν_2
	b. Enter F-value with d.f. = (ν_1,ν_2)	$F_{\alpha/2}$	[STO]31	$F_{\alpha/2}$
	c. Enter F-value with d.f. = (ν_2,ν_1)	$F_{\alpha/2}$	[STO]41	$F_{\alpha/2}$
	d. Calculate Limits		[R/S]	ℓ
			[X<>Y]	u

See Previous Note (NV) for One-Sided Limits

Register Contents

00	xxx		10		20		30		40	$\hat{\theta}$
01	Σy		11	1	21		31	$t_{\alpha/2}, F_{\alpha/2}$	41	$F_{\alpha/2}$
02	Σy^2		12		22		32	SE	42	
03	Σx	Used	13	n_x	23	Used	33	s_p	43	
04	Σx^2		14	CCDF	24		34	θ_0	44	
05	Σxy		15	$\nu(\nu_1)$	25		35		45	
06	n_y		16	ν_2	26		36		46	
07	Used		17	Used	27	s_d	37	$\bar{y}$	47	$\bar{x}$, $\bar{d}$
08	Used		18		28	H_1-code	38	s_y	48	s_x
09	Used		19		29	P(ts)	39	$e(\hat{\theta} \pm e)$	49	

Assignments

ZS-6	J
DEP	P
DEI	I
OP11	ENG
X TO Y	j

Labels Used

00	A	a
01	B	b
02	C	c
04	D	d
05	E	
06		
08		
09		
11		
12		
13		

Examples ZS-6

(1) Before (X) and After (Y) weights were recorded in lbs. after two weeks of dieting. Find a 95% CI for the mean difference $\mu_x - \mu_y$ and conduct a significance test of equality test of equality of means. Test for a weight loss of at least 2 lbs.

x:	119	122	136	130	129	136	134	133	119	115
y:	114	119	134	126	119	137	124	127	119	107

Solution:

ZS STEP		ENTER	PRESS	DISPLAY	COMMENTS
DE	0.		[J]	DATA?	
	1a.		[P]	0.0000	Initialize ZS-6 for paired data entry.
		119	[ENTER]	119.0000	Enter first x-value.
		114	[R/S]	1.0000	Follow with first y-value.
		122	[ENTER]	122.0000	Enter second x-value.
		119	[R/S]	2.0000	Follow with second y-value.
		136	[ENTER]	136.0000	Enter succeeding pairs.
		134	[R/S]	3.0000	
		130	[ENTER]	130.0000	
		126	[R/S]	4.0000	
		129	[ENTER]	129.0000	
		119	[R/S]	5.0000	
		136	[ENTER]	136.0000	
		137	[R/S]	6.0000	
		134	[ENTER]	134.0000	
		124	[R/S]	7.0000	
		133	[ENTER]	133.0000	
		127	[R/S]	8.0000	
		119	[ENTER]	119.0000	
		119	[R/S]	9.0000	
		115	[ENTER]	115.0000	Enter last x-value
		107	[R/S]	10.	Follow with last y-value (n = 10)
DE	2.		[d]	0.0000	ZS program processes data.
PN	3a.		[B]	9.0000	Calculates and displays ν = 9 = d.
	3b.	2.262	[R/S]	1.9389	Enter $t_{.025}$ from t-table and display $\ell \doteq 1.94$
			[X<>Y]	7.4611	Display u so CI is (1.94, 7.46).
PN	2a.	0	[b]	0.0000	Enter H_1-code = 0 for two-sided test.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
	0	[R/S]	0.0039	Use $\theta_0 = 0$ for this case and find P = 0.0039; reject at usual levels.
		[RCL]30	3.8504	Display value of ts.
PN 2a.	1	[b]	1.0000	Use H_1-code of 1 making $H_0 : \mu_x - \mu_y \leq 2$ the disclaimer.
	2	[R/S]	0.0271	With $\theta_0 = 2$, P-value is enough to reject at $\alpha = 5\%$.

(2) A test of color perception was administered to a control group (X) and an experimental group (Y) with results:

x: 16.3 14.7 12.3 13.5 16.0 17.1 17.3

y: 14.0 16.5 17.7 15.9 18.0 16.3

Analyze the two groups for differences. Also test for equality of variances.

<u>Solution assuming $\sigma_x = \sigma_y$:</u>

DE 0.		[J]	DATA?	Initialize ZS-6 for independent data entry.
1b.	16.3	[R/S]	1.000	Enter first x-value.
	14.7	[R/S]	2.0000	Continue x-values assuming data
	12.3	[R/S]	3.0000	are independent.
	13.5	[R/S]	4.0000	
	16.0	[R/S]	5.0000	
	17.1	[R/S]	6.0000	
	17.3	[R/S]	7.0000	Last x-value entered; $n_x = 7$.
		[j]	0.0000	Prepare for y-values.
	14	[R/S]	1.0000	Begin entering y-value
	16.5	[R/S]	2.0000	(as with label B in ST-04)
	17.7	[R/S]	3.0000	
	15.9	[R/S]	4.0000	
	18	[R/S]	5.0000	
	16.3	[R/S]	6.0000	Conclude y-entries; $n_y = 6$
DE 2.		[d]	0.0000	Process data.
INA 2.	0	[c]	0.0000	Enter H_1-code for two-sided test.
	0	[R/S]	0.2740	Display P-value (for $\theta_0 = 0$) of 0.27;
		[RCL]30	-1.1512	Accept H_0 (ts = -1.15).
INA 3.		[C]	11.0000	Reveal d.f. = $n_x + n_y - 2 = 11$ for this case.
	2.201	[R/S]	-3.1615	Entering $t_{.025} = 2.201$, CI runs from
		[X<>Y]	0.9900	$\ell = -3.16$ to $u = 0.99$ which does include 0.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
	Solution assuming $\sigma_x \neq \sigma_y$:			
INB 1.	Same as INA so data are already entered and processed.			
INB 2.		[A]	10.0000	Calculates degrees of freedom for
	2.228	[R/S]	-3.1404	approximate CI based on Welch t.
		[X<>Y]	.9690	Comes close to preceding solution.
INB 3.	0	[a]	0.0000	Begins Welch t-test with H_1-code
	0	[R/S]	0.2663	followed by $\theta_0 = 0$ to yield about the same P-value.
	To test for $\sigma_x^2 = \sigma_y^2$:			
NV 1.	Same as INA			
NV 2.	0	[SF]04	0.0000	H_1-code for two-sided test. Flag 4 signals NV a test is being calle for.
		[D]	.5645	Large P-value; accept $\sigma_x^2 = \sigma_y^2$ with
		[RCL]30	1.7290	ts = 1.73.
NV 3a.				To take a CI point of view
		[D]	6.0000	Displays $\nu_1 = n_x - 1$.
		[R/S]	5.0000	Displays $\nu_2 = n_y - 1$
NV 3b.	6.98	[STO]31	6.9800	Enter $F_{.025}$ with d.f. = (6,5).
NV 3c.	5.99	[STO]41	5.9900	Enter $F_{.025}$ with reversed d.f. = (
		[R/S]	0.2477	Shows a 95% CI that includes the
		[X<>Y]	10.3565	value 1. Accept $\sigma_x^2 = \sigma_y^2$.

(3) A sample of 60 exponential times to failure averaged $\bar{x}$ = 1306 hrs. Six independent times averaged $\bar{y}$ = 1247 hours. Test $H_0 : \mu_x \leq \mu_y$.

Solution:

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
Exp 1.	60	[STO]13	60.0000	Enter Summary Data
	6	[STO]06	6.0000	
	1306	[STO]47	1,306.0000	
	1247	[STO]37	1,247.0000	Data entry concluded.
Exp 2.	1	[SF]04	1.0000	Enter H_1-code for $H_1 : \mu_x > \mu_y$ and set flag 4 to signal H-test.
		[E]	0.5043	P-value of 0.50 obtained; do not reject.
Exp 3a.		[E]	120.0000	$\nu_1 = 2n_x$ displayed.
		[R/S]	12.0000	$\nu_2 = 2n_y$ displayed.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
3b.	2.35	[STO]31	2.3500	$F_{.05}$ for $\nu_1 = 100$, $\nu_2 = 10$ entered
	1	[STO]41	1.0000	1 store in R_{41} to compute lower CI
		[R/S]	0.4457	Lower bound on μ_x/μ_y displayed.

Chapter 7 Proportions

This chapter represents the most successful transfer of programs of all. Indeed, the only remarks that need to be added to the existing programs is to remind you once more that all references to register R_{03} in TI are to be replaced with R_{06} in HP, that [X<>Y] is the HP version of [x t] (so that any reference tp TI R_T should be replaced by R_Y). Finally, since ZS-7 has been assigned to [J], you should press the latter key whenever you need to access the programs here and is the only initialization necessary.

S-7 (Assigned [J])	USER INSTRUCTIONS (HP)	SIZE 050 Σ REG 01

TEP	PROCEDURE	ENTER	PRESS	DISPLAY
(p)	Bernoulli Parameter			
0.	Initialization (if not already in ZS-7)		[J]	0.0000
1.	Data Entry			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Proportion Estimate	$\hat{p}$	[STO]40	$\hat{p}$
2.	Test $H_0 : p = p_0$			
	a. Enter H_1-code*	H_1-code	[b]	H_1-code
	b. Enter p_0 and Compute P-value OR:	p_0	[R/S]	P
	b'. For n Large (Normal Test)	p_0	[c]	P
3.	CI for p for n large			
	Enter Risk and Calculate Limits	$\alpha/2$	[C]	ℓ
	Note: For One-sided Limits, Enter α and Ignore ℓ or u.		[X<>Y]	u
4.	CI for p for n small			
	a. Find first d.f. for F.		[B]	ν_1
			[R/S]	ν_2
	b. Enter $F_{\alpha/2}$ with d.f. = (ν_1,ν_2)	$F_{\alpha/2}$	[STO]31	$F_{\alpha/2}$
	c. Find second d.f. for F		[R/S]	ν_1
			[R/S]	ν_2
	d. Enter $F_{\alpha/2}$ with new d.f.	$F_{\alpha/2}$	[STO]41	$F_{\alpha/2}$
	e. Calculate limits		[R/S]	ℓ
			[X<>Y]	u
	Note: For Lower One-sided Limit, enter F_α at Step 3b, 1 at Step 3d and Ignore u. For Upper One-sided Limit, enter 1 at Step 3b, F_α at Step 3d and Ignore ℓ.			
$(p_x - p_y)$	Two Bernoulli Parameters			
1.	Data Entry			
	a. Enter Sample Sizes	n_x	[STO]13	n_x
		n_y	[STO]06	n_y
	b. Enter Proportion Estimates	$\hat{p}_x$	[STO]47	p_x
		$\hat{p}_y$	[STO]37	$\hat{p}_y$

*
$$H_1\text{-code} = \begin{cases} 1 \text{ if } H_1 : \theta > \theta_0 \\ 0 \text{ if } H_1 : \theta \neq \theta_0 \\ -1 \text{ if } H_1 : \theta < \theta_0 \end{cases}$$

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
2.	Test $H_0 : p_x = p_y$			
	Enter H_1-code and Calculate P-value	H_1-code	[a]	P
3.	CI for $p_x - p_y$			
	Enter Risk and Calculate Limits	$\alpha/2$	[A]	ℓ
			[X<>Y]	u
	Note: For One-sided Limits Enter α and Ignore ℓ or u.			

Register Contents

00		10		20	Used (20–27)	30		40	$\hat{\theta}$
01		11	Used	21		31	$z_{\alpha/2}, F_{\alpha/2}$	41	$F_{\alpha/2}$
02		12	Used	22		32	SE	42	
03		13	n_x	23		33	Used	43	
04	u	14		24		34	θ_0	44	
05	ℓ	15		25		35		45	
06	$n(n_y)$	16		26		36		46	
07		17	Used	27		37	$\hat{p}_y$	47	$\hat{p}_x$
08	BIN p(0)	18	Used	28	H_1-code	38		48	
09		19	Used	29	p(ts)	39	$e(\hat{\theta}+e)$	49	

Assignments

ZS-7	J

Labels Used

01	A	a
02	B	b
03	C	
04		
05		
06		

ZS-7 EXAMPLES

(1) In nine independent Bernoulli trials, there were exactly four successes. Find a 95% CI for p and test $H_0 : p = 0.5$.

Solution:

ZP STEP		ENTER	PRESS	DISPLAY	COMMENTS
B(p)	1.	9.	[STO]06	9.0000	Enter sample size.
		.44...	[STO]40	0.44...	Enter $\hat{p} = 4/9$, the estimate of p.
	4a.		[B]	12.0000	Since n is small find first pair
			[R/S]	8.0000	of d.f. = (10,10).
	4b.	4.20	[STO]31	4.2000	Enter first $F_{.025}$ percentile.
	4c.		[R/S]	10.0000	Discover revised d.f. = (12,8).
			[R/S]	10.0000	
	4d.	3.72	[STO]41	3.72	Store second $F_{.025}$ percentile.
			[R/S]	0.1370	Lower confidence limit displayed
			[X<>Y]	0.7881	and u found in R_Y.
	3.	0.	[b]	0.0000	Enter H_1-code for $H_1 : p \neq 0.5$.
		0.5	[R/S]	1.0000	Significance level 1; accept H_0.

(2) A device was tested 25 times and passed 23 times. Find a lower one-sided CI on p, the probability of passing. Test $H_0 : p \geq 0.95$.

Solution:

ZP STEP		ENTER	PRESS	DISPLAY	COMMENTS
B(p)	1.	25	[STO]06	25.0000	Enter data as above.
		23÷25	[STO]40	0.9200	$\hat{p} = 23/25 = 0.92$
	2a.	-1	[b]	-1.0000	Enter H_1-code for $H_1 : p < 0.95$.
	2b.	0.95	[c]	0.2456	Comparing with large sample test.
	4a.		[B]	6.0000	Initial d.f. for small n CI (to
			[R/S]	46.0000	be ignored along with ν_2.
	4b.	2.29	[STO]31	2.2900	Following instructions store 1 in
	4c.		[R/S]	48.0000	R_{31}. Calculate new d.f. $\nu_1 = 6$
			[R/S]	4.0000	and $\nu_2 = 46$.
	4d.	1	[STO]41	1.0000	Enter $F_{.05}$ for d.f. = (6,50) and
			[R/S]	0.7700	calculate lower confidence bound.

(4) A sample of size 100 was taken from a lot with replacement and 2 defective items were found. Test the manufactures claim that $p < 0.05$ at $\alpha = .01$.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
Solution:				
B(p) 1.	100.	[STO]06	100.0000	Enter data as usual.
	.02	[STO]40	0.0200	
2a.	-1.	[b]	-1.0000	H_1-code for H_1 : $p < .05$, the null hypothesis being H_0 : $p \geq .05$, the disclaimer.
2b.	.05	[R/S]	0.1183	Enter p_0 and find P = 0.12 supporting H_0 not H_1.
2b'.	.05	[c]	0.0843	Compare normal test.

(3) In a random sample of 500 men (X) 350 were found to favor a certain political issue. In a similar sample of 300 women (Y) 200 were so inclined. Is there any real difference between sexes on this issue?

Solution: To test H_0 : $p_x = p_y$				
$B(p_x - p_y)$ 1a.	500	[STO]13	500.0000	Enter first sample size.
	300	[STO]06	300.0000	Enter second sample size.
1b.	0.7	[STO]47	0.7000	Enter first proportion estimate $\hat{p}_x$.
	2/3	[STO]37	0.6667	Enter second proportion estimate $\hat{p}_y$.
2.	0.	[a]	0.3248	Enter H_1-code for H_1 : $p_x \neq p_y$
		[RCL]30	.9847	and find P = 0.32 with ts = .98. Data supports H_0.
3.	.025	[A]	-0.0335	A 95% CI for the difference $u_x - \mu_y$
		[X<>Y]	0.1001	extends from -.03 to + .10; include 0.

Chapter 8 Analysis of Variance

The big change here is the data entry which is via STAT PAC through the Analysis of Variance routines provided there. Unfortunately, those routines are not complete enough to accomplish all of the goals set out in the text so that they too had to be supplemented with program ZS-8, whose user instructions follow.

Section 8.2: One-Way Classifications

On page 95, you may replace the reference to ST-22 with execution of FCCDF in ZSTAT. If you will consult the user instructions, you will see that the program utilizes subroutine ΣAOVONE, assigned to [H] for convenience, in place of the TI program ST-06, referred to on page 197. After pressing [H] and seeing the display ΣAOVONE, you follow Steps 3-5 for inputting data (a model example is provided following the user instructions). A press of [E] while still in ΣAOVONE will then output most of the AOV table. The only, but important, missing item is the prob-value and that is calculated at Step 3 in ZS-8 by exiting ΣAOVONE with a press of [J] followed by [A]. The Scheffe´ confidence intervals discussed in the very next section follow precisely the same user instructions as the TI and are duplicated in the HP User Instructions that follow.

Section 8.4: Two-Way Classifications

In this section, the program ΣAOVTWO in STAT PAC is used for data entry in place of ST-06. This subroutine is assigned to [I] in ZS-8 and, once pressed, the instructions for data entry and output discussed on page 23 of the STAT PAC handbook should be followed. (Again, a model problem is provided at the end of the user instructions for ZS-8). This will provide for only part of the Two-Way table as displayed in this section of the text (and most other textbooks on the subject). To complete the table, you need to exit ΣAOVTWO by pressing [J] and then [C] will output the remaining items needed for the table including the all-important prob-values. Once again, the instructions for implementing the Sheffe´ confidence interval formulas discussed in the next section are identical to those for the TI and are duplicated in the user instructions that follow.

ZS-8 (Assigned [J]) USER INSTRUCTIONS (HP) SIZE 060

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
AOV-1	One-Way Analysis of Variance			
0.	INITIALIZATION (if not already in ZS-8)		[J]	xxxx
1.	Enter Data Using ΣAOVONE		[H]	ΣAOVONE
	NOTE: Record Each Row Mean			
2.	Calculate AOV Table Entries			
	NOTE: These Steps may NOT be repeated once Step 3 is executed.		[E]	SS
			[R/S]	RSS
			[R/S]	ESS
			[R/S]	K-1
			[R/S]	N-K
			[R/S]	N-1
			[R/S]	MRSS
			[R/S]	MESS
			[R/S]	F
3.	Exit ΣOVONE and compute P-value	F	[J]	F
			[A]	P
4.	Confidence Intervals for Contrasts (After Step 2)			
	a. Initialize		[e]	0.0000
	b. Enter Contrast Data (Repeat for each i; ignore any $c_i = 0$)	c_i	[R/S]	c_i
		$\bar{x}_i$	[R/S]	$\bar{x}_i$
		n_i	[R/S]	i
	c. Enter F-percentile d.f. = (K-1,N-K), and calculate CI	F_α	[a]	ℓ
			[X<>Y]	u
	NOTE 1: Steps 3abc may be repeated.			
	NOTE 2: These Steps are also valid if R_{03} and R_{48} are manually stored.			

REGISTER CONTENTS

00	SS	10	Used	20		30	F	40		50	$\Sigma c_i \bar{x}_i$
01	RSS	11	N-K	21	FCDF	31	P	41		51	Last c_i
02	ESS	12	Used	22		32		42		52	Last $\bar{x}$
03	K-1	13		23		33		43		53	$\Sigma c_i^2/n_i$
04	Used	14		24		34		44		54	Used
05	Used	15	R-1	25		35		45		55	
06	M	16	N-K	26		36		46		56	
07	Used	17	Used	27		37		47		57	
08	Used	18		28		38		48	MESS	58	
09	K	19	for	29		39		49	e	59	

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
AOV-2	Two-Way Analysis of Variance			
0.	Initialize (if not in ZS-8)		[J]	x.xxxx
1.	Enter Data Using ΣAOVTWO		[I]	ΣAOVTWO
2.	Calculate Row and Column Means			
	Calculate Row Means After each Row		[R/S]	SUM_i
	entry (Record). Repeat i = 1,...,R.	C	[÷]	$\bar{x}_{i.}$
	Calculate Column Means After each		[R/S]	
	Column entry (Record). Repeat	R	[÷]	$\bar{x}_{.j}$
	j = 1,2,...,C.			
3.	Calculate AOV Table Entries		[E]	RSS
	NOTE: These Steps may NOT be repeated		[R/S]	CSS
	once Step 4 is executed		[R/S]	SS
			[R/S]	ESS
			[R/S]	R-1
			[R/S]	C-1
			[R/S]	(R-1)(C-1)
			[R/S]	F_R
			[R/S]	F_C
4.	Exit ΣAOVTWO		[J]	F_C
5.	Complete the AOV output	F_C	[C]	MRSS
			[R/S]	MCSS
			[R/S]	MESS
			[R/S]	P_R
			[R/S]	P_C

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
6.	Confidence Intervals for Posterior Contrasts			
	a. Initialize		[E]	0.0000
	b. Enter Contrast Data	c_i	[R/S]	c_i^2
	(Repeat for each i (or j))	$\bar{x}_{i.}$ (or $\bar{x}_{.j}$)	[R/S]	i (or j)
	c. CI for Row Contrast $\Sigma c_i \mu_{i.}$	F_α	[D]	ℓ
	d.f. = (R-1,(R-1)(C-1))		[X<>Y]	u
	d. CI for Column Contrast $\Sigma c_i \mu_{.j}$	F_α	[d]	ℓ
	d.f. = (C-1,(R-1)(Ψ-1))		[X<>Y]	u
	NOTE 1: Steps 4abc or 4 abd may be repeated.			
	NOTE 2: These steps are also valid if the contents of registers R_{48}, R_{58}, R_{59} below are stored manually.			

REGISTER CONTENTS:

00	Used	10		20	30	ts	40		50	$\Sigma c\bar{x}$
01	R	11	(R-1)(C-1)	21	31		41		51	last c
02	C	12	RSS	22	32		42		52	last $\bar{x}$
03	RC	13	CSS	23	33		43		53	Σc
04	x..	14	R-1	24	34		44		54	Used
05	x^2..	15	C-1	25	35		45		55	
06	$\bar{x}$..	16	(R-1)(C-1)	26	36		46		56	F_R
07	MESS	17	Used	27	37		47		57	F_C
08		18		28	38		48	MESS	58	R-1
09		19		29	39		49	e	59	C-1

Assignments

ZS-8	J
ΣAOVONE	H
ΣAOVTWO	I

Labels Used

01	A	a
02	C	d
03	D	e
	E	

EXAMPLES ZS-8

(1) Three types of solvents are tested on grease-soaked material and the amount of grease removed in milligrams is noted for several specimens with the following results:

Solvent A	11	12	12	
Solvent B	13	15		
Solvent C	12	10	11	11

Test the hypothesis of no differences in solvents.

Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
		[J]	x.xxxx	
AOV-1, 1.		[H]	ΣAOVONE	Call for ΣAOVONE in the module.
ΣAOV 2.	11	[A]	1.00	Enter data for the first row.
	12	[A]	2.00	Enter data for the first row.
	12	[A]	3.00	Row 1 data entry concluded.
ΣAOV 5.		[R/S]	11.67	First row mean $\bar{x}_1$ calculated. Record!
		[R/S]	0.58	s for row 1 and row sum; ignore and
		[R/S]	35.00	go on to enter data for second row.
ΣAOV 2.	13	[A]	1.00	Running count begins anew.
	15	[A]	2.00	Row 2 data entry concluded.
ΣAOV 5.		[R/S]	14.00	Row mean $\bar{x}_2$ calculated. Record!
		[R/S]	1.41	Row 2 s and sum; ignore and proceed
		[R/S]	28.00	to enter data for third row.
ΣAOV 2.	12	[A]	1.00	
	10	[A]	2.00	
	11	[A]	3.00	
	11	[A]	4.00	Row 3 data entry concluded.
ΣAOV 5.		[R/S]	11.00	Value of x_3. (Record)
		[R/S]	0.82	Value of s and sum; ignore. Data
		[R/S]	44.00	entry concluded.
ΣAOV 6.		[E]	16.89	Value of SS displayed for total.
		[R/S]	12.22	Value of RSS
		[R/S]	4.67	ESS displayed
		[R/S]	2.00	d.f. for RSS
		[R/S]	6.00	d.f. for ESS displayed
		[R/S]	8.00	d.f. for SS displayed
		[R/S]	6.11	Value of MRSS
		[R/S]	0.78	Value of MESS

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
		[R/S]	7.86	F-ratio = MRSS/MESS.
		[J]	7.8571	Exit ΣAOVONE.
		[A]	0.0211	P-value of the F-ratio.

(2) Find Scheffe 95% confidence intervals for the contrast $\mu_1-0.5\mu_2-0.5\mu_3$ where MESS = 105.97 and K = 3, N-k = 18; $\bar{x}_1$ = 103.71, $\bar{x}_2$ = 92, $\bar{x}_3$ = 89, $n_i \equiv 7$.

Solution:

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
AOV-1. 2.	2	[STO]14	2.0000	ν_1 = K-1 = 2 stored in R_{14}
	105.97	[STO]48	105.9700	MESS stored in R_{48} as required.
AOV-1. 3.		[e]	0.0000	Initialize CI routine.
	1	[R/S]	1.0000	First of triple triple $c_1,\bar{x},n$, entered.
	103.71	[R/S]	103.7100	Second member of triple
	7	[R/S]	1.0000	Sample size n_1; count of 1 (triple) displayed.
	-0.5	[R/S]	-0.5000	Beginning entry of $c_2,\bar{x}_2,n_2$.
	92	[R/S]	92.0000	
	7	[R/S]	2.0000	Running count of 2 displayed.
	-0.5	[R/S]	-0.5000	Entering final triple
	89	[R/S]	89.0000	
	7	[R/S]	3.0000	Entry completed.
	3.49	[a]	0.6203	$F_{.05}$ for d.f. = (2,20) entered
		[X<>Y]	25.7997	and confidence limits displayed. Conclude contrast significantly different from 0.

(3) Five teachers were matched with three schools to produce the following average scores on a standardized examination after a unit of instructions

Schools \ Teachers	A	B	C	D	E	$\bar{x}_{i\cdot}$
I	53	47	46	50	49	49
II	61	55	52	58	54	56
III	51	51	49	54	50	51
$\bar{x}_{\cdot j}$	55	51	49	54	51	

ZS	STEP	ENTER	PRESS	DISPLAY	COMMENTS

Construct a two-way AOV table and find CI's for $\mu_{1.}-\mu_{2.}$ and $\mu_{.1}-\mu_{.3}$.

Solution:

ZS	STEP	ENTER	PRESS	DISPLAY	COMMENTS
			[J]	x.xxxx	
AOV-2	1.		[I]	ΣAOVTWO	Call for ΣAOVTWO from the module.
ΣAOV	3.	53	[A]	1.00	Enter first data value from row 1.
		47	[A]	2.00	Continue entering data from row 1.
		46	[A]	3.00	.
		50	[A]	4.00	.
		49	[A]	5.00	.until all the data from row 1 are entered
			[R/S]	245.00	
ΣAOV	5.	5	[÷]	49.00	Calculate and record row mean $\bar{x}_1$.
ΣAOV	3.	61	[A]	1.00	Go on with first value from row 2
		55	[A]	2.00	and continue
		52	[A]	3.00	until all of
		58	[A]	4.00	the data from row 2
		54	[A]	5.00	have been entered.
ΣAOV	5.		[R/S]	280.00	Calculate and
		5	[÷]	56.00	record $\bar{x}_2$.
ΣAOV	3.	51	[A]	1.00	Continue non-stop with data
		51	[A]	2.00	entry from the third and
		49	[A]	3.00	last row
		54	[A]	4.00	
		50	[A]	5.00	
ΣAOV	5.		[R/S]	255.00	Calculate and
		5	[÷]	51.00	record $\bar{x}_3$.
ΣAOV	6.		[R/S]	COLUMN-WISE	Prepare for column computations.
ΣAOV	8.	53	[A]	1.00	Enter first value from column 1.
		61	[A]	2.00	Enter second value from column 1.
		51	[A]	3.00	Enter last value from column 1.
ΣAOV	10.		[R/S]	165.00	Calculate $\bar{x}_{.1}$.
			[÷]	55.00	and record.
ΣAOV	8.	47	[A]	1.00	Repeat for column 2
		55	[A]	2.00	
		51	[A]	3.00	
ΣAOV	10.		[R/S]	153.00	Calculate and
		3	[÷]	51.00	record $\bar{x}_{.2}$

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
ΣAOV 8.	46	[A]	46.00	Repeat for column 3
	52	[A]	52.00	
	49	[A]	49.00	
ΣAOV 10.		[R/S]	147.00	Calculate and
	3	[÷]	49.00	record $\bar{x}_{\cdot 3}$
ΣAOV 8.	50	[A]	50.00	Repeat for column 4
	58	[A]	58.00	
	54	[A]	54.00	
ΣAOV 10.		[R/S]	162.00	Calculate and
	3	[÷]	54.00	record $\bar{x}_{\cdot 4}$
ΣAOV 8.	49	[A]	49.00	Repeat for column 5.
	54	[A]	54.00	
	50	[A]	50.00	
ΣAOV 10.		[R/S]	153.00	Calculate and
	3	[÷]	51.00	record $\bar{x}_{\cdot 5}$
ΣAOV 11.		[E]	130.00	Data compiled and RSS displayed
		[R/S]	72.00	CSS displayed.
		[R/S]	224.00	SS total sum of squares.
		[R/S]	22.00	ESS displayed
		[R/S]	2.00	Row d.f. = R-1 = 2 displayed.
		[R/S]	4.00	Column d.f. = C-1 = 4 displayed
		[R/S]	8.00	Error d.f. = (R-1)(C-1) displayed
		[R/S]	23.64	F_R displayed
		[R/S]	6.55	F_C displayed
		[J]	6.5455	Exit ΣAOVTWO and enter ZS-8
ZS-7 5.		[C]	65.0000	MRSS displayed
		[R/S]	18.0000	MCSS displayed
		[R/S]	2.7500	MESS displayed
		[R/S]	0.0004	P-value for F_R computed and displayed
		[R/S]	0.0122	P-value for F_C
4.		[E]	0.0000	Initialize for Scheffe CI's
	1	[R/S]	1.0000	Enter c_1 = 1 to find CI for $\mu_{1\cdot} - \mu_{2\cdot}$.
	49	[R/S]	1.0000	Enter row mean $\bar{x}_{1\cdot}$.
	-1	[R/S]	1.0000	Enter c_2 = -1 for contrast $\mu_{1\cdot} - \mu_{2\cdot}$.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
	56	[R/S]	2.0000	All non-zero c's now entered.
	4.46	[D]	-10.1324	$F_{.05}$ = 4.46 for d.f. = (2,8)
		[X<>Y]	-3.8676	ℓ is displayed followed by u.
		[RCL]49	3.1324	The value of e retrieved from R_{49} for further comparisons.
		[E]	0.0000	Re-initialize C.I. program.
	1	[R/S]	1.0000	Enter c_1 for contrast $\mu_{.1} - \mu_{.3}$.
	55	[R/S]	1.0000	$\bar{x}_{.1}$, the first column mean is entered.
	-1	[R/S]	1.0000	Enter $c_2 = -1$
	49	[R/S]	2.0000	Enter third column mean $\bar{x}_{.3}$.
	3.84	[d]	0.6934	Enter $F_{.05}$ for d.f. = (4,8) and calculate Lower limit.
		[X<>Y]	11.3066	Upper limit retrieved from R_Y.
		[RCL]49	5.3066	Value of e found in R_{49} for further comparisons.

Chapter 9 Simple Linear Regression

It is rather surprising that the HP is not hard-wired for at least simple linear regression as is the TI and many lesser hand-held calculators. There is a routine in STAT PAC, but, just as with the TI statistics module, no provision is made for confidence intervals, tests of hypotheses, etc.. In order to make the HP output match the discussions given in the text, we have created a simple data entry scheme in a program called ZS-9 (assigned the label [I] for convenient access). Once that program is accessed, you have only to press [D] (for data) and enter the successive pairs of numbers as per Step 2 of the instructions. At the conclusion of entry, press [e] to compile the data whereupon the degrees of freedom will be displayed for you. At this point, you may enter a t-percentile if you like. In any event, the effect of entering data this way will force the register contents to almost agree with those of the TI entry, with a couple of notable exceptions. Referring to page 237, HP R_{06} as usual must replace TI R_{03} and then the TI R_{04}, R_{05}, R_{06} become HP R_{03}, R_{04}, R_{05}, respectively. As usual, the HP functions MEAN and SDEV replace TI [$\bar{x}$] and [INV][$\bar{x}$] and will output the same quantities. There is a subroutine within ZS-9 called [Op]11 whose execution will exactly match that of TI [Op]11 as referred to in this chapter. Try this on the data in Example 9.1 to verify the results published on page 238. Similarly, there are subroutines in ZS-9 called [Op]14 and [Op]15 that will function in exactly the same way as their TI counterparts referred to in the text. In Note 2 on page 238, HP will display the message DATA ERROR if the data all have the same carrier value. Similarly, in Note 1 on page 250, HP will display the message ALL REALS to signify that the CI does not exist. Otherwise, all of the instructions for the various regression routines through Section 9.4 are identical to those given in the book for the TI. For that reason only Step 1 needs to be modified and that has been taken care of in the User Instructions that follow on the next page.

Section 9.5: Curve Fitting

The procedures in this section utilize the TI statistics module and, fortunately, most of them are duplicated in the HP STAT PAC under the same title, Curve Fitting, beginning on page 32 of the STAT PAC handbook. The only problem is that the HP notation differs slightly from that of TI. Thus, TI b is HP a and TI m is HP b . You will have to make that adjustment in order to use your HP for solving problems in this section. The output of label [E] in that program, however, will produce the right estimated equations and can be used to verify the numbers given in Example 9.9 as well as most of the exercises. The one big departure is that HP makes no allowance for creating your own user defined transformation so that examples like 9.10 on page 265 cannot be checked. Those are not too common, however, so that for the main type of transformations you are likely to run into in practice, what is provided by STAT PAC will suffice. All of the answers to the problems, with the exception of 40e, can be verified with those routines.

ZS-9 (Assigned [I])	USER INSTRUCTIONS (HP)			SIZE 050 Σ REG 01
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
I 0.	<u>Initialization</u> (if not already in ZS-9)		[I]	0.0000
1.	Clear registers		[D]	0.0000
2.	Enter data (repeat i = 1,2,...,n)	x_i	[ENTER]	x_i
		y_i	[R/S]	i
3.	Compile data		[e]	n-2
4.	Enter percentile for CI's (d.f. = n-2) (may also store manually in R_{31} at any time)	$t_{\alpha/2}$	[R/S]	$t_{\alpha/2}$
SLOPE				
1	CI for m		[A]	ℓ
			[X<>Y]	u
2	Test H_0:m = m_0.			
	a. Enter H_1-code.*	H_1-code	[a]	H_1-code
	b. Enter hypothesized value.	m_0	[R/S]	P
INT				
1	CI for b		[B]	ℓ
			[X<>Y]	u
2	Test H_0:b = b_0.			
	a. Enter H_1-code.	H_1-code	[b]	H_1-code
	b. Enter hypothesized value.	b_o	[R/S]	P
ı at x_o	CI for $mx_0 + b$	x_0	[C]	ℓ
			[X<>Y]	u
at x_0	PI for $Y_0 = mx_0 + b + e$	x_0	[c]	ℓ
			[X<>Y]	u
DISC	CI for x^*, when y^* is observed	y^*	[d]	ℓ
			[X<>Y]	u
CORR	Test H_0:ρ = 0. Enter H_1-code. Note: Valid whenever n-2 εR_{15} and r ε R_{44}	H_1-code	[E]	P

*Note: H_1-code $\begin{cases} -1 \text{ for } H_1:\theta < \theta_0 \\ 0 \text{ for } H_1:\theta \neq \theta_0 \\ 1 \text{ for } H_1:\theta > \theta_0 \end{cases}$

REGISTER CONTENTS:

00	Used	10		20		30	ts	40	$\hat{\theta}$
01	Σy_i	11		21		31	$t_{\alpha/2}$	41	Used
02	Σy_i^2	12		22	Used	32		42	d
03	Σx_i	13		23	by	33	s	43	$y^*-\bar{y}$
04	Σx_i^2	14	n-1	24	TCDF	34	θ_0	44	r
05	$\Sigma x_i y_i$	15	$\nu = n-2$	25		35	$s_{\hat{m}}$	45	$\hat{m}$
06	n	16		26		36	$s_{\hat{B}}$	46	$\hat{b}$
07	$\Sigma(y_i-\bar{y})^2$	17		27		37	$s_{\hat{Y}}$	47	$\bar{x}$
08	$\Sigma(x_i-\bar{x})^2$	18		28	H_1-code	38	$s_{\hat{M}x_0+\hat{B}}$	48	$\bar{y}$
09		19		29	P(ts)	39	$e(\hat{\theta}\pm e)$	49	

For curve fitting, consult STAT PAC p. 32.

Assignments

ZS-9	I
OP12	H
OP13	P
OP14	h
OP15	i

Labels Used

01	A	a
02	B	b
03	C	c
04	D	d
05	E	e

AMPLE ZS-9

The resistance of a length of wire is thought to be a linear function of the mperature of the wire. For a given temperature, errors in readings of resistance e normally distributed with mean 0 and variance σ^2. The following readigs were made the temperatures indicated.

Temperature	0	10	20	30	40	50
Resistance	22.6	25.1	29.0	29.9	33.4	34.8

(a) Estimate the regression of resistance on temperature.

(b) Estimate the resistance if temperature is 25.

(c) Estimate the temperature if resistance is 30.

(d) Find a 95% confidence interval for the slope, m.

(e) Find a 95% confidence interval for the intercept b.

(f) Find a 95% confidence interval for the expected resistance when temperature is 25.

(g) Find a 95% prediction interval for the measured response when temperature is 25.

(h) Find a 95% discrimination interval for the temperature at which a resistance of 30 is observed.

(i) Test the hypotheses H_0: $m = 0$ vs. H_1: $m \neq 0$.

(j) Test the hypotheses H_0: $b \leq 20$ vs. H_1: $b > 20$.

(k) Calculate the coefficient of determination.

(l) Test H_0: $\rho = 0$ vs. H_1: $\rho \neq 0$.

SOLUTIONS:

ZS	STEP	ENTER	PRESS	DISPLAY	COMMENTS
I	0.		[I]	x.xxxx	
	1.		[D]	0.0000	Clear data registers
I	2.	0	[ENTER]	0.0000	Enter x_1.
		22.6	[R/S]	1.0000	Enter y_1, update data base; (x,y) count displayed.
		10	[ENTER]	10.0000	Enter x_2.
		25.1	[R/S]	2.0000	Enter y_2, update data base
		20	[ENTER]	20.0000	Enter x_3.
		29	[R/S]	3.0000	(x,y) - count displayed.
		30	[ENTER]	30.0000	
		29.9	[R/S]	4.0000	(x,y) - count displayed.
		40	[ENTER]	40.0000	
		33.4	[R/S]	5.0000	(x,y) - count displayed.
		50	[ENTER]	50.0000	
		34.8	[R/S]	6.0000	Value of n = 6 concludes data entry.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
I 3.		[e]	4.0000	Compile data; display d.f. = 4.
I 4.	2.776	[R/S]	2.7760	Enter $t_{.025}$ for d.f. = 4.
		[H]	22.9333	$\hat{b}$
		[X<>Y]	0.2480	$\hat{m}$; $\hat{y}$ = .248x + 22.93 answers (a).
	25	[h]	29.1333	$\hat{y}$ for x = 25 answers (b).
	30	[i]	28.4946	$\hat{x}$ for y = 30 answers (c).
SLOPE 1.		[A]	0.1983	ℓ
		[X<>Y]	.2977	u, so CI is .198 < m < .298, answering (d).
INT 1.		[B]	21.4294	ℓ
		[X<>Y]	24.4373	u, so CI is 21.4 < b < 24.4, answering (e).
μ at x_0	25	[C]	28.2850	ℓ
		[X<>Y]	29.9817	u, so CI is 28.28 < 25m + b < 29.9 answering (f).
Y at x_0	25	[c]	26.8889	ℓ
		[X<>Y]	31.3778	u, so PI is 26.89 < Y_0 < 31.38, answering (g)
DISC	30	[d]	19.3744	ℓ
		[X<>Y]	37.9069	u, so CI is 19.37 < x* < 37.91, answering (h).
SLOPE 2a.	0	[a]	0.0000	Enter H_1-code for H_1: m ≠ 0
2b.	0	[R/S]	0.0002	Significance of test; reject H_0; answers (i).
INT 2a.	1	[b]	1.000	Enter H_1-code for H_1: b > 20
2b.	20	[R/S]	0.0028	Significance of test; reject H_0; answers (j).
		[P]	0.9897	Calculates and displays r
		[x^2]	0.9796	r^2 = 0.98 is the answer to (k).
CORR	0	[U][E][U]	0.0002	Significance of test of H_0: ρ = 0 (must agree with (i)).

[U] = [USER]

Chapter 10 Multiple Regression

Only the data entry scheme differs from the TI version of this program. The regression program ΣMLRXY in STAT PAC is utilized for entering the data in the HP version and partial processing takes place in that program. Further processing takes place in program ZS-10 (assigned to label [J] for easy entry from STAT PAC) so that even the register contents (with the slight modification given below) and the remaining instructions will match those given in the book.

Once ZS-10 is entered, a press of [d] will force the pointer to STAT PAC program ΣMLRXY. Data are then entered as follows: first, x and y are successively entered with the [ENTER] key and then the value of z with [A]. At the conclusion of data entry, pressing [E] will cause partial processing, ending with a display of the coefficient of determination. It is at this point that STAT PAC must be exited and ZS-10 entered with a press of [J]. Then, pressing [e] will cause the rest of the processing to take place. Thereafter, the user instructions for ZS-10 may be followed to the letter. For that reason, only the DE instructions need to be modified and are summarized below. The usual sample problem is presented starting on the following page.

SIZE 050

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
DE	Data Entry			
0	Initialization		[J] [d]	0.0000 ΣMLRXY
1	ENTER DATA (repeat i=1,...,n)	xi yi zi	[ENTER] [ENTER] [A]	xi yi i
2	Compile Data (partial) Complete compile		[E] [J] [e]	R^2 0.0000 n-3
3	Enter t-percentile (d.f. = n-3)	$t_{\alpha/2}$	[R/S]	$t_{\alpha/2}$

Assignments

ZS-10	J
ΣMLRXY	e

Labels Used

01	A	a
02	B	b
	C	c
	D	d
	E	e

Register Contents

40	
41	
42	
43	
44	
45	
46	$\hat{a}_0$
47	$\hat{a}_1$
48	$\hat{a}_2$
49	

ZS-10 EXAMPLE.

The data below represent characteristics of a sample of automobiles.

Weight	3810	4220	2900	3290	3400	3920	4350
Horsepower	255	180	16	120	100	140	150
Cost	7999	9221	8222	9010	10099	11019	11219

(a) Regress cost on weight and horsepower.

(b) Predict the cost of an automobile weighting 5,000 lbs. and having 160 horsepower.

(c) Determine the significance of horsepower for predicting cost.

(d) Find a 95% confidence interval for the coefficient of weight.

(e) Estimate σ.

(f) Find the coeffficient of determination.

Solution:

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
DE 0.		[J]	0.0000	Enter program ZS-10
1.		[d]	ΣMLRXY	Initialize ΣMLRXY for data entry.
	3810	[ENTER]	3810.00	Enter x_1.
	255	[ENTER]	255.00	Enter y_1.
	7999	[A]	1.00	Enter z_1 completing one triple.
	4220	[ENTER]	4220.00	Enter x_2.
	180	[ENTER]	180.00	Enter y_2.
	9221	[A]	2.00	Enter z_2 completing two triples.
	2900	[ENTER]	2900.00	Enter x_3.
	96	[ENTER]	96.00	Enter y_3.
	8222	[A]	3.00	Enter z_3 completing three triples.
	3290	[ENTER]	3290.00	Enter x_4.
	120	[ENTER]	120.00	Enter y_4.
	9010	[A]	4.00	Enter z_4, completing four triples.
	3400	[ENTER]	3400.00	Enter x_5.
	100	[ENTER]	100.00	Enter y_5.
	10099	[A]	5.00	Enter z_5, completing five triplets
	3920	[ENTER]	3920.00	Enter x_6.
	140	[ENTER]	140.00	Enter y_6.
	11019	[A]	6.00	Enter z_6, completing six triplets.
	4350	[ENTER]	4350.00	Enter x_7.
	150	[ENTER]	150.00	Enter y_7.
	11219	[A]	7.00	Enter z_7, completing last triplet.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
		[E]	0.80	Process data and display R^2.
		[J]	0.8050	Exit ΣMLRXY and enter ZS-10
I 2.		[e]	4.0000	Process trivariate data further and display $\nu = 4$.
I 3.	2.776	[R/S]	2.7760	Enter $t_{.025}$ for CI's.
D		[D]	3361.7167	Display $\hat{a}_0$.
		[R/S]	2.4657	Display $\hat{a}_1$.
		[R/S]	-19.7686	Recall and display $\hat{a}_2$.
	Regression equation:		$\hat{z} = 3361.72 + 2.466x - 19.769y$.	
E	5000	[E]	0.0000	Prepare to predict Z.
	160	[R/S]	12,527.0724	Predicted cost.
C	0	[c]	0.0000	Testing $H_0 : a_2 = 0$ vs. $H_1 : a_2 \neq 0$.
	0	[R/S]	0.0318	Significance level for a_2 (ts = -3.2).
B		[B]	0.6786	Lower 95% limit for a_1.
		[X<>Y]	4.2527	Upper 95% limit for a_1.
		[RCL]33	691.7057	$\hat{\sigma} = s$.
		[RCL]27	0.8050	Recall and display $R^2 = .80$.

APPENDIX

In the appendix that follows, you will find a complete listing of the programs discussed in the previous sets of User Instructions. These programs are named according to their ZP or ZS application by chapter and, occasionally, by section. To implement the programs, the first step is to key in each step into your calculator exactly as it appears in the listing. (Consult the Owner's Handbook for any instructions that may be unfamiliar.) Next, you should assign various subroutines using the function ASN according to the assignments listed just after the register contents in the User Instructions for each program. Then place your HP41-C in USER mode and record the program on a magnetic card for future reference.

```
01•LBL "ZP2"
02 ΣREG 01
03 CLΣ
04 20
05 STO 07
06 21
07 STO 08
08 0
09 RTN

10•LBL A
11 STO IND 07
12 RCL 06
13 1
14 +
15 STOP
16 STO IND 08
17 RDN
18 X<>Y
19 R↑

20•LBL 02
21 STO IND 08
22 Σ+
23 2
24 ST+ 07
25 ST+ 08
26 RCL 06
27 RTN

28•LBL B
29 2
30 *
31 18
32 +
33 STO 09
34 1
35 +
36 STO 10
37 RCL IND 09
38 RCL IND 10
39 *
40 RCL 05
41 /
42 RTN

43•LBL a
44 RCL 05
45 RTN

46•LBL D
47 RCL IND 07
48 STOP
49 STO IND 08
50 GTO 02

51•LBL d
52 STO 00
53 1/X
54 STO 13

55•LBL 03
56 RCL IND 07
57 RCL 13
58 XEQ 02
59 DSE 00
60 GTO 03
61 RTN

62•LBL E
63 1/X
64 STO 13

65•LBL 04
66 STOP
67 STO IND 07
68 RCL 13
69 XEQ 02
70 GTO 04

71•LBL C
72 1
73 STO 03
74 -
75 STO 00
76 365
77 STO 01
78 STO 02

79•LBL 05
80 1
81 ST- 01
82 RCL 01
83 RCL 02
84 /
85 ST* 03
86 DSE 00
87 GTO 05
88 1
89 RCL 03
90 -
91 RTN

92•LBL 08
93 "H=?"
94 PROMPT
95 STO 11
96 "R=?"
97 PROMPT
98 STO 12
99 1
100 STO 14
101 RCL 12
102 0
103 X=Y?
104 GTO 10
105 RTN

106•LBL b
107 XEQ 08

108•LBL 09
109 RCL 11
110 ST* 14
111 1
112 ST- 11
113 DSE 12
114 GTO 09

115•LBL 10
116 RCL 14
117 STOP

118•LBL c
119 XEQ 08
120 X>Y?
121 GTO 12
122 RDN
123 RCL 11
124 X<>Y
125 X>Y?
126 GTO 12

127•LBL 11
128 RCL 11
129 ST* 14
130 1
131 ST- 11
132 RCL 12
133 ST/ 14
134 DSE 12
135 GTO 11
136 GTO 10

137•LBL 12
138 0
139 STOP
140 END
```

```
01♦LBL "ZP3-2"
 02 CLRG
 03 20
 04 STO 01
 05 21
 06 STO 02
 07 0
 08 RTN

 09♦LBL A
 10 STO IND 01
 11 STOP
 12 STO IND 02
 13 1
 14 ST+ 03
 15 2
 16 ST+ 01
 17 ST+ 02
 18 RCL 03
 19 RTN

 20♦LBL 01
 21 RCL 03
 22 STO 00
 23 0
 24 STO 06
 25 STO 07
 26 20
 27 STO 01
 28 21
 29 STO 02
 30 RTN

 31♦LBL 02
 32 RCL IND 01
 33 STO 09
 34 XEQ B

 35♦LBL 05
 36 STO 04
 37 X↑2
 38 STO 05
 39 RCL IND 02
 40 ST* 04
 41 ST* 05
 42 RCL 04
 43 ST+ 06
 44 RCL 05
 45 ST+ 07
 46 2
 47 ST+ 01
 48 ST+ 02
 49 RTN

 50♦LBL E
 51 XEQ 01

 52♦LBL 03
 53 RCL IND 01
 54 XEQ 05
 55 DSE 00
 56 GTO 03

 57♦LBL 06
 58 RCL 07
 59 RCL 06
 60 X↑2
 61 -
 62 STO 08
 63 RCL 06
 64 RTN

 65♦LBL D
 66 XEQ 01

 67♦LBL 04
 68 XEQ 02
 69 DSE 00
 70 GTO 04
 71 GTO 06

 72♦LBL C
 73 STO 08
 74 0
 75 STO 10
 76 21
 77 STO 02

 78♦LBL 07
 79 RCL IND 02
 80 ST+ 10
 81 2
 82 ST+ 02
 83 DSE 08
 84 GTO 07
 85 RCL 10
 86 RTN

 87♦LBL B
 88 END
```

```
01•LBL "ZP3-3"
02 CF 02
03 0
04 STOP

05•LBL A
06 STO 00
07 FS? 02
08 GTO 02
09 RCL 14
10 STO 24
11 1/X
12 STO 22
13 RCL 15
14 ST- 24
15 ST* 22
16 RCL 22
17 STO 11
18 STO 12
19 1
20 -
21 CHS
22 STO 21
23 ST* 12
24 RCL 13
25 STO 03
26 ST* 11
27 ST* 12
28 ENTER↑
29 RCL 14
30 -
31 CHS
32 RCL 14
33 1
34 -
35 /
36 ST* 12

37•LBL 01
38 RCL 24
39 RCL 13
40 X<=Y?
41 GTO 09
42 0
43 STO 16
44 SF 02
45 GTO 02

46•LBL 09
47 RCL 24
48 STO 01
49 RCL 13
50 STO 02
51 XEQ "PMTOH"
52 STO 16
53 RCL 14
54 STO 01
55 RCL 13
56 STO 02
57 XEQ "PMTOH"
58 ST/ 16
59 SF 02

60•LBL 02
61 0
62 STO 20
63 RCL 16
64 STO 06
65 STO 07
66 0
67 ENTER↑
68 RCL 00
69 X=Y?
70 GTO 05

71•LBL 03
72 1
73 ST+ 20
74 RCL 20
75 ENTER↑
76 RCL 15
77 -
78 1
79 -
80 CHS
81 ENTER↑
82 0
83 X<>Y
84 X<=Y?
85 GTO 04
86 CHS
87 2
88 +
89 RCL 14
90 +
91 RCL 13
92 -
93 ENTER↑
94 0
95 X<>Y
96 X<=Y?
97 GTO 04
98 1
99 -
100 ENTER↑
101 0
102 X=Y?
103 GTO 06
104 X<>Y
105 RCL 20
106 *
107 1/X
108 ENTER↑
109 RCL 13
110 ENTER↑
111 RCL 20
112 -
113 1
114 +
115 *
116 ENTER↑
117 RCL 15
118 ENTER↑
119 RCL 20
120 -
121 1
122 +
123 *

124•LBL 04
125 ST* 06
126 RCL 06
127 ST+ 07
128 DSE 00
129 GTO 03

130•LBL 05
131 RCL 06
132 RCL 07
133 RTN

134•LBL 06
135 1
136 STO 06
137 RCL 15
138 STO 01
139 RCL 20
140 STO 02
141 XEQ "CMBOH"
142 STO 23
143 RCL 14
144 STO 01
145 RCL 13
146 STO 02
147 XEQ "CMBOH"
148 ST/ 23
149 RCL 23
150 GTO 04

151•LBL a
152 XEQ A
153 1
154 -
155 CHS
156 RTN

157•LBL 10
158 1
159 STO 04
160 RCL 02
161 0
162 X=Y?
163 GTO 10
164 RTN

165•LBL "PMTOH"
166 XEQ 10

167•LBL 19
168 RCL 01
169 ST* 04
170 1
171 ST- 01
172 DSE 02
173 GTO 19

174•LBL 10
175 RCL 04
176 RTN

177•LBL "CMBOH"
178 XEQ 10
179 X>Y?
180 GTO 12
181 RDN
182 RCL 01
183 X<>Y
184 X>Y?
185 GTO 12

186•LBL 11
187 RCL 01
188 ST* 04
189 1
190 ST- 01
191 RCL 02
192 ST/ 04
193 DSE 02
194 GTO 11
195 GTO 10

196•LBL 12
197 0
198 STOP

199•LBL B
200 STO 00
201 FS? 02
202 GTO 07
203 RCL 13
204 STO 11
205 STO 12
206 RCL 15
207 RCL 14
208 /
209 STO 22
210 ST* 11
211 ST* 12
212 1
213 -
214 CHS
215 STO 21
216 ST* 12
217 RCL 13
218 Y↑X
219 STO 16
220 STO 06
221 STO 07
222 SF 02

223•LBL 07
224 0
225 STO 20
226 RCL 16
227 STO 06
228 STO 07
229 RCL 00
230 0
231 X=Y?
232 GTO 05

233•LBL 08
234 1
235 ST+ 20
236 RCL 20
237 RCL 13
238 -
239 CHS
240 1
241 +
242 RCL 20
243 /
244 RCL 22
245 *
246 RCL 21
247 /
248 ST* 06
249 RCL 06
250 ST+ 07
251 DSE 00
252 GTO 08
253 GTO 05

254•LBL b
255 XEQ B
256 1
257 -
258 CHS
259 RTN

260•LBL E
261 RCL 12
262 RCL 11
263 RTN
264 END
```

```
01♦LBL "ZP3-4"
02 CF 01
03 CF 02
04 CF 03
05 CF 04
06 0
07 STOP

08♦LBL B
09 STO 00
10 FS? 02
11 GTO 07
12 FS? 04
13 GTO 11
14 RCL 22
15 STO 11
16 STO 12
17 1
18 -
19 CHS
20 STO 21
21 ST* 12
22 LN
23 RCL 13
24 ST* 11
25 ST* 12
26 *
27 CHS
28 228
29 X<=Y?
30 GTO 11
31 RCL 21
32 RCL 13
33 Y↑X
34 STO 16
35 STO 06
36 STO 07
37 SF 02

38♦LBL 07
39 0
40 STO 20
41 RCL 16
42 STO 06
43 STO 07
44 RCL 00
45 0
46 X=Y?
47 GTO 05

48♦LBL 08
49 1
50 ST+ 20
51 RCL 20
52 CHS
53 RCL 13
54 +
55 1
56 +
57 RCL 20
58 /
59 RCL 22
60 *
61 RCL 21
62 /
63 ST* 06
64 RCL 06
65 ST+ 07
66 DSE 00
67 GTO 08

68♦LBL 05
69 RCL 06
70 RCL 07
71 RTN

72♦LBL 11
73 RCL 00
74 .5
75 +
76 RCL 11
77 -
78 RCL 12
79 SQRT
80 /
81 STO 10
82 XEQ "ZCDF"
83 STO 23
84 RCL 00
85 .5
86 -
87 RCL 11
88 -
89 RCL 12
90 SQRT
91 /
92 XEQ "ZCDF"
93 RCL 23
94 -
95 CHS
96 LASTX
97 SF 04
98 RTN

99♦LBL b
100 XEQ B
101 ENTER↑
102 1
103 -
104 CHS
105 RTN

106♦LBL E
107 RCL 12
108 RCL 11
109 RTN

110♦LBL C
111 STO 00
112 FS? 03
113 GTO 13
114 FS? 04
115 GTO 11
116 RCL 22
117 RCL 13
118 *
119 STO 11
120 STO 12
121 228
122 X<=Y?
123 GTO 11
124 X<>Y
125 CHS
126 E↑X
127 STO 16
128 STO 06
129 STO 07
130 SF 03

131♦LBL 13
132 0
133 STO 20
134 RCL 16
135 STO 06
136 STO 07
137 RCL 00
138 X=0?
139 GTO 05

140♦LBL 14
141 1
142 ST+ 20
143 RCL 20
144 1/X
145 RCL 11
146 *
147 ST* 06
148 RCL 06
149 ST+ 07
150 DSE 00
151 GTO 14
152 GTO 05

153♦LBL c
154 XEQ C
155 ENTER↑
156 1
157 -
158 CHS
159 RTN

160♦LBL A
161 STO 00
162 FS? 04
163 GTO 15
164 FS? 01
165 GTO 18
166 RCL 22
167 1/X
168 STO 11
169 X↑2
170 STO 12
171 1/X
172 SQRT
173 1
174 -
175 CHS
176 STO 21
177 ST* 11
178 ST* 12
179 RCL 22
180 RCL 13
181 ST* 11
182 ST* 12
183 Y↑X
184 STO 16
185 STO 06
186 STO 07
187 SF 01

188♦LBL 18
189 0
190 STO 20
191 RCL 16
192 STO 06
193 STO 07
194 RCL 00
195 X=0?
196 GTO 05

197♦LBL 19
198 1
199 ST+ 20
200 RCL 20
201 RCL 13
202 +
203 1
204 -
205 RCL 20
206 /
207 RCL 21
208 *
209 ST* 06
210 RCL 06
211 ST+ 07
212 DSE 00
213 GTO 19
214 GTO 05

215♦LBL 15
216 RCL 21
217 ST* 11
218 CF 04
219 RCL 00
220 GTO A

221♦LBL a
222 XEQ A
223 ENTER↑
224 1
225 -
226 CHS
227 RTN

228♦LBL J
229 RCL 13
230 -
231 XEQ A
232 RCL 21
233 ST/ 11
234 SF 04
235 RCL 06
236 RCL 07
237 RTN

238♦LBL D
239 STO 00
240 FS? 02
241 GTO 20
242 RCL 22
243 1
244 -
245 CHS
246 STO 21
247 STO 12
248 RCL 22
249 1/X
250 STO 11
251 X↑2
252 ST* 12
253 SF 02
```

```
254+LBL 20
255 RCL 21
256 ENTER↑
257 RCL 00
258 1
259 -
260 Y↑X
261 RCL 22
262 *
263 ENTER↑
264 ENTER↑
265 RCL 21
266 RCL 00
267 Y↑X
268 ENTER↑
269 1
270 -
271 CHS
272 RTN

273+LBL d
274 XEQ D
275 ENTER↑
276 1
277 -
278 CHS
279 RTN

280+LBL "ZCDF"
281 STO 03
282 ENTER↑
283 *
284 2
285 /
286 CHS
287 E↑X
288 PI
289 2
290 *
291 SQRT
292 /
293 STO 04
294 RCL 03
295 X<0?
296 GTO 27
297 SF 00

298+LBL 23
299 1
300 RCL 03
301 .2316419
302 *
303 +
304 1/X
305 ENTER↑
306 ENTER↑
307 ENTER↑
308 1.330274429
309 *
310 -1.821255978
311 +
312 *
313 1.781477937
314 +
315 *
316 -.356563782
317 +
318 *
319 .31938153
320 +
321 *
322 RCL 04
323 *
324 FS? 00
325 GTO 29
326 RTN

327+LBL 27
328 RCL 03
329 CHS
330 STO 03
331 XEQ 23
332 1
333 X<>Y
334 -

335+LBL 29
336 CF 00
337 ENTER↑
338 ENTER↑
339 1
340 -
341 CHS
342 END
```

```
01•LBL "ZP4"
02 CF 01
03 FIX 4
04 0
05 STOP

06•LBL "ZCDF"
07 STO 25
08 ENTER↑
09 *
10 2
11 /
12 CHS
13 E↑X
14 PI
15 2
16 *
17 SQRT
18 /
19 STO 26
20 RCL 25
21 X<0?
22 GTO 07
23 SF 00

24•LBL 03
25 1
26 RCL 25
27 .2316419
28 *
29 +
30 1/X
31 ENTER↑
32 ENTER↑
33 ENTER↑
34 1.330274429
35 *
36 -1.821255978
37 +
38 *
39 1.781477937
40 +
41 *
42 -.356563782
43 +
44 *
45 .319381530
46 +
47 *
48 RCL 26
49 *
50 FS? 00
51 GTO 09
52 RTN

53•LBL 07
54 RCL 25
55 CHS
56 STO 25
57 XEQ 03
58 1
59 X<>Y
60 -

61•LBL 09
62 CF 00
63 ENTER↑
64 ENTER↑
65 1
66 -
67 CHS
68 RTN

69•LBL c
70 .5
71 X<>Y
72 X>Y?
73 XEQ 11
74 ENTER↑
75 *
76 1/X
77 LN
78 SQRT
79 STO 00
80 .010328
81 *
82 .802853
83 +
84 RCL 00
85 *
86 2.515517
87 +
88 RCL 00
89 .001308
90 *
91 .189269
92 +
93 RCL 00
94 *
95 1.432788
96 +
97 RCL 00
98 *
99 1
100 +
101 /
102 RCL 00
103 X<>Y
104 -
105 FS? 01
106 CHS
107 GTO 12

108•LBL 11
109 SF 01
110 1
111 -
112 CHS
113 RTN

114•LBL 12
115 CF 01
116 STO 19
117 RTN

118•LBL "RNDMU"
119 RCL 09
120 9821
121 *
122 .211327
123 +
124 FRC
125 STO 09
126 RTN

127•LBL a
128 XEQ "RNDMU"
129 1
130 RCL 14
131 +
132 *
133 RCL 13
134 +
135 INT
136 FIX 0
137 STOP
138 FIX 4
139 Σ+
140 RTN

141•LBL "GEN-INI"
142 FIX 4
143 ΣREG 01
144 CLΣ
145 "SEED?"
146 PROMPT
147 STO 09
148 RTN

149•LBL C
150 RCL 11
151 -
152 RCL 12
153 SQRT
154 /
155 STO 10
156 XEQ "ZCDF"
157 STO 07
158 1
159 -
160 CHS
161 RCL 07
162 RTN

163•LBL D
164 XEQ C
165 STO 08
166 X<>Y
167 STOP
168 XEQ C
169 ST- 08
170 RCL 08
171 1
172 +
173 RCL 08
174 CHS
175 RTN

176•LBL d
177 XEQ c
178 RCL 12
179 SQRT
180 *
181 RCL 11
182 +
183 RTN

184•LBL A
185 STO 00
186 FS? 05
187 GTO 15
188 FS? 01
189 GTO 16
190 RCL 13
191 RCL 14
192 +
193 2
194 /
195 STO 11
196 RCL 14
197 RCL 13
198 -
199 STO 15
200 X↑2
201 12
202 /
203 STO 12
204 SF 01
205 RCL 00

206•LBL 16
207 RCL 13
208 -
209 RCL 15
210 /
211 STO 07
212 1
213 -
214 CHS
215 RCL 07
216 RTN

217•LBL 15
218 RCL 15
219 *
220 RCL 14
221 -
222 CHS
223 CF 05
224 RTN

225•LBL b
226 RCL 12
227 RCL 11
228 RTN

229•LBL E
230 STO 00
231 FS? 01
232 GTO 17
233 RCL 22
234 1/X
235 STO 11
236 X↑2
237 STO 12
238 SF 01

239•LBL 17
240 RCL 00
241 RCL 22
242 *
243 CHS
244 E↑X
245 ENTER↑
246 ENTER↑
247 1
248 -
249 CHS
250 STO 07
251 RTN

252•LBL e
253 LN
254 RCL 22
255 /
256 CHS
257 RTN

258•LBL B
259 XEQ "RND
260 LN
261 RCL 2
262 /
263 CHS
264 STO 0
265 Σ+
266 RCL 0
267 RTN

268•LBL G
269 XEQ "RND
270 XEQ d
271 STO 00
272 Σ+
273 RCL 00
274 RTN

275•LBL "XBA
276 MEAN
277 RTN

278•LBL "SD"
279 SDEV
280 END
```

```
01◆LBL "ZP5"
02 ΣREG 01
03 CLΣ
04 ΣREG 07
05 CLΣ
06 ΣREG 13
07 CLΣ
08 20
09 STO 19
10 0

11◆LBL 01
12 STOP

13◆LBL A
14 STO IND 19
15 STO 09
16 1
17 ST+ 19
18 ST+ 03
19 RCL 03
20 STOP

21◆LBL B
22 STO IND 19
23 STO 10
24 1
25 ST+ 19
26 RCL 03
27 STOP

28◆LBL C
29 STO IND 19
30 ST+ 07
31 STO 08
32 1
33 ST+ 19
34 RCL 03
35 GTO 01

36◆LBL E
37 RCL 03
38 STO 00
39 20
40 STO 19

41◆LBL 02
42 RCL IND 19
43 STO 01
44 STO 06
45 X↑2
46 STO 04
47 1
48 ST+ 19
49 RCL IND 19
50 STO 02
51 ST* 06
52 X↑2
53 STO 05
54 1
55 ST+ 19
56 RCL IND 19
57 ST* 01
58 ST* 02
59 ST* 04
60 ST* 05
61 ST* 06
62 RCL 01
63 ST+ 11
64 RCL 02
65 ST+ 13
66 RCL 04
67 ST+ 12
68 RCL 05
69 ST+ 14
70 RCL 06
71 ST+ 15
72 1
73 ST+ 19
74 DSE 00
75 GTO 02
76 RCL 11
77 X↑2
78 ST- 12
79 RCL 13
80 X↑2
81 ST- 14
82 RCL 11
83 RCL 13
84 *
85 ST- 15
86 RCL 15
87 RCL 12
88 SQRT
89 /
90 RCL 14
91 SQRT
92 /
93 STO 16
94 RTN

95◆LBL D
96 0
97 STO 17
98 STO 18
99 RCL 03
100 STO 00
101 20
102 STO 19

103◆LBL 03
104 RCL IND 19
105 STO 09
106 1
107 ST+ 19
108 RCL IND 19
109 STO 10
110 1
111 ST+ 19
112 XEQ a
113 STO 07
114 X↑2
115 STO 08
116 RCL IND 19
117 ST* 07
118 ST* 08
119 RCL 07
120 ST+ 17
121 RCL 08
122 ST+ 18
123 1
124 ST+ 19
125 DSE 00
126 GTO 03
127 RCL 17
128 X↑2
129 ST- 18
130 RCL 18
131 RCL 17
132 RTN

133◆LBL d
134 RCL 11
135 STOP
136 RCL 12
137 STOP
138 RCL 13
139 STOP
140 RCL 14
141 STOP
142 RCL 15
143 STOP
144 RCL 16
145 RTN
146 GTO d

147◆LBL a
148 END
```

```
01♦LBL "ZS-2"
02 ΣREG 01
03 CLΣ
04 FIX 4
05 0
06 STOP

07♦LBL "RNDMU"
08 RCL 09
09 9821
10 *
11 .211377
12 +
13 FRC
14 STO 09
15 RTN

16♦LBL "RNDMAB"
17 XEQ "RNDMU"
18 RCL 14
19 RCL 13
20 -
21 *
22 RCL 13
23 +
24 RTN

25♦LBL "RNDMI"
26 XEQ "RNDMAB"
27 INT
28 FIX 0
29 RTN

30♦LBL 19
31 STO 25
32 ENTER↑
33 *
34 2
35 /
36 CHS
37 E↑X
38 PI
39 2
40 *
41 SQRT
42 /
43 STO 26
44 RCL 25
45 X<0?
46 GTO 07
47 SF 00

48♦LBL 03
49 1
50 RCL 25
51 .2316419
52 *
53 +
54 1/X
55 ENTER↑
56 ENTER↑
57 ENTER↑
58 1.330274429
59 *
60 -1.821255978
61 +
62 *
63 1.781477937
64 +
65 *
66 -.356563782
67 +
68 *
69 .31938153
70 +
71 *
72 RCL 26
73 *
74 FS? 00
75 GTO 09
76 RTN

77♦LBL 07
78 RCL 25
79 CHS
80 STO 25
81 XEQ 03
82 1
83 X<>Y
84 -

85♦LBL 09
86 CF 00
87 ENTER↑
88 ENTER↑
89 1
90 -
91 CHS
92 RTN

93♦LBL c
94 .5
95 X<>Y
96 X>Y?
97 XEQ 11
98 ENTER↑
99 *
100 1/X
101 LN
102 SQRT
103 STO 00
104 .010328
105 *
106 .802853
107 +
108 RCL 00
109 *
110 2.515517
111 +
112 RCL 00
113 .001308
114 *
115 .189269
116 +
117 RCL 00
118 *
119 1.432788
120 +
121 RCL 00
122 *
123 1
124 +
125 /
126 RCL 00
127 X<>Y
128 -
129 FS? 01
130 CHS
131 GTO 12

132♦LBL 11
133 SF 01
134 1
135 -
136 CHS
137 RTN

138♦LBL 12
139 CF 01
140 STO 19
141 RTN

142♦LBL C
143 STO 00
144 RCL 17
145 -
146 RCL 18
147 /
148 STO 20
149 XEQ 19
150 STO 07
151 1
152 -
153 CHS
154 RCL 07
155 RTN

156♦LBL D
157 XEQ C
158 STO 08
159 X<>Y
160 STOP
161 XEQ C
162 ST- 08
163 RCL 08
164 1
165 +
166 RCL 08
167 CHS
168 RTN

169♦LBL d
170 XEQ c
171 RCL 18
172 *
173 RCL 17
174 +
175 RTN

176♦LBL "GEN-INI"
177 FIX 4
178 ΣREG 01
179 CLΣ
180 "SEED?"
181 PROMPT
182 STO 09
183 RTN

184♦LBL b
185 XEQ "RNDMU"
186 XEQ d
187 STO 00
188 Σ+
189 RCL 00
190 RTN

191♦LBL B
192 XEQ "RNDMU"
193 XEQ e
194 STO 00
195 Σ+
196 RCL 00
197 RTN

198♦LBL E
199 STO 00
200 RCL 16
201 1/X
202 STO 17
203 STO 18
204 RCL 00
205 RCL 16
206 *
207 CHS
208 E↑X
209 ENTER↑
210 ENTER↑
211 1
212 -
213 CHS
214 STO 07
215 RTN

216♦LBL e
217 1
218 -
219 CHS
220 LN
221 RCL 16
222 /
223 CHS
224 RTN

225♦LBL 20
226 "PMTERS?"
227 PROMPT
228 STO 21
229 STO 17
230 STOP
231 STO 22
232 ST* 17
233 1
234 -
235 CHS
236 STO 23
237 RCL 22
238 *
239 RCL 21
240 *
241 SQRT
242 STO 18
243 0
244 STOP

245♦LBL A
246 STO 00
247 RCL 23
248 RCL 21
249 Y↑X
250 STO 24
251 STO 25
252 STO 26
253 0
254 STO 10
255 RCL 00
256 X=Y?
257 GTO 03

258♦LBL 06
259 1
260 ST+ 10
261 RCL 10
262 CHS
263 RCL 21
264 +
265 1
266 +
267 RCL 1
268 /
269 RCL 2
270 *
271 RCL 2
272 /
273 ST* 2
274 RCL 2
275 ST+ 2
276 DSE 0
277 GTO 06

278♦LBL 0
279 RCL 26
280 1
281 -
282 CHS
283 RCL 26
284 RCL 25
285 RTN

286♦LBL "MU-SI
287 FIX 4
288 RCL 07
289 RCL 05
290 X↑2
291 -
292 SQRT
293 STO 18
294 RCL 06
295 STO 17
296 RTN

297♦LBL a
298 RCL 18
299 RCL 17
300 RTN

301♦LBL "BS
302 XROM "ΣBS
303 RTN

304♦LBL "XB
305 MEAN
306 RTN

307♦LBL "
308 SDEV
309 RTN

310♦LBL "
311 RDN
312 RTN
313 END
```

```
01•LBL "ZS-3"
 02 STOP

 03•LBL C
 04 RCL 13
 05 RCL 12
 06 -
 07 RTN

 08•LBL B
 09 MEAN
 10 STO 08
 11 RCL 06
 12 STO 08
 13 31
 14 STO 30
 15 0
 16 STO 07

 17•LBL 01
18 RCL IND 30
 19 RCL 08
 20 -
 21 ABS
 22 ST+ 07
 23 1
 24 ST+ 30
 25 DSE 08
 26 GTO 01
 27 RCL 07
 28 RCL 06
 29 /
 30 RTN

 31•LBL b
 32 MEAN
 33 STO 08
 34 RCL 19
 35 STO 08
 36 31
 37 STO 14
 38 32
 39 STO 15
 40 0
 41 STO 07

 42•LBL 02
43 RCL IND 14
 44 RCL 08
 45 -
 46 ABS
47 RCL IND 15
 48 *
 49 ST+ 07
 50 2
 51 ST+ 14
 52 ST+ 15
 53 DSE 08
 54 GTO 02
 55 RCL 07
 56 RCL 06
 57 /
 58 RTN

 59•LBL c
 60 RCL 13
 61 +
 62 RCL 12
 63 -
 64 RTN

 65•LBL d
 66 CF 01
 67 0
 68 RTN

 69•LBL D
 70 FS? 01
 71 GTO 03
 72 30
 73 STO 08

 74•LBL 03
 75 1
 76 ST+ 08
77 RCL IND 08
 78 SF 01
 79 RTN

 80•LBL e
 81 CF 01
 82 ΣREG 07
 83 CLΣ
 84 ΣREG 13
 85 CLΣ
 86 ΣREG 01
 87 CLΣ
 88 SF 07
 89 31
 90 STO 15
 91 STO 30
 92 0
 93 STO 19
 94 RTN

 95•LBL E
 96 STO 14

 97•LBL 04
 98 RCL IND 15
 99 XEQ a
 100 XEQ 05
 101 1
 102 ST+ 15
 103 DSE 14
 104 GTO 04
 105 RCL 19
 106 RTN

 107•LBL A
 108 XEQ a

 109•LBL 05
 110 STO 09
111 STO IND 30
 112 FS? 07
 113 XEQ 13
 114 ST+ 01
 115 RCL 09
 116 *
 117 ST+ 02
 118 1
 119 ST+ 06
 120 ST+ 19
 121 ST+ 30
 122 RCL 12
 123 RCL 09
 124 X<=Y?
 125 STO 12
 126 RCL 13
 127 X<>Y
 128 X>Y?
 129 STO 13
 130 RCL 19
 131 RTN

 132•LBL 13
 133 STO 12
 134 STO 13
 135 CF 07
 136 RTN

 137•LBL "MSD"
 138 SDEV
 139 STO 08
 140 RDN
 141 XEQ 12
 142 RCL 08
 143 XEQ 12
 144 RTN

 145•LBL 12
 146 X↑2
 147 RCL 06
 148 1
 149 -
 150 *
 151 RCL 06
 152 /
 153 RTN

154•LBL "XBAR"
 155 MEAN
 156 RTN

 157•LBL "SD"
 158 SDEV
 159 RTN

 160•LBL a
 161 END
```

ST-03

```
01♦LBL "ST-03"
02 0
03 STOP

04♦LBL e
05 ΣREG 01
06 CF 06
07 CLRG
08 31
09 STO 30
10 1
11 STO 10
12 SF 07
13 0
14 STOP

15♦LBL A
16 STO 18
17 STO IND 30
18 FS? 06
19 GTO 01
20 1
21 ST+ 30

22♦LBL 02
23 RCL 18
24 STO 09
25 FS? 07
26 XEQ 03
27 RCL 10
28 *
29 ST+ 01
30 RCL 09
31 *
32 ST+ 02
33 RCL 10
34 ST+ 06
35 1
36 ST+ 19
37 RCL 12
38 RCL 09
39 X<=Y?
40 STO 12
41 RCL 13
42 X<>Y
43 X>Y?
44 STO 13
45 RCL 19
46 RTN

47♦LBL B
48 STO 10
49 1
50 ST+ 30
51 RCL 10
52 STO IND 30
53 1
54 ST- 30
55 SF 06
56 RCL 10
57 RTN

58♦LBL 01
59 2
60 ST+ 30
61 GTO 02

62♦LBL 03
63 STO 12
64 STO 13
65 CF 07
66 END
```

ST-07/9

```
01♦LBL "ST-07/9"
02 0
03 STOP

04♦LBL e
05 ΣREG 12
06 CLΣ
07 ΣREG 18
08 CLΣ
09 ΣREG 24
10 CLΣ
11 ΣREG 01
12 CLΣ
13 31
14 STO 30
15 0
16 STO 00
17 "CELLS?"
18 PROMPT
19 STO 09
20 "XMIN?"
21 PROMPT
22 STO 12
23 "W=?"
24 PROMPT
25 STO 11
26 RCL 09
27 *
28 RCL 12
29 +
30 STO 13
31 0
32 RTN

33♦LBL A
34 STO 08
35 STO IND 30
36 RCL 13
37 X<=Y?
38 GTO 01
39 RDN
40 RCL 12
41 X>Y?
42 GTO 01
43 -
44 RCL 11
45 /
46 INT
47 14
48 +
49 STO 00
50 1
51 ST+ 29
52 ST+ 30
53 ST+ IND 00
54 ST+ 06
55 RCL 03
56 ST+ 01
57 RCL 03
58 *
59 ST+ 02
60 RCL 29
61 RTN

62♦LBL 01
63 0
64 /
65 RTN

66♦LBL d
67 "N=?"
68 PROMPT
69 31
70 STO 30
71 +
72 STO 05

73♦LBL 02
74 RCL IND 30
75 XEQ A
76 RCL 05
77 RCL 30
78 X=Y?
79 GTO 03
80 GTO 02

81♦LBL 03
82 RCL 29
83 RTN

84♦LBL c
85 1
86 ST+ 00
87 ST+ 10
88 RCL 09
89 RCL 00
90 X<=Y?
91 GTO 04
92 "STOP"
93 PROMPT
94 STOP

95♦LBL 04
96 RCL IND 10
97 STO 07
98 STO 08
99 FIX 0
100 STOP
101 FIX 4
102 RCL 11
103 RCL 00
104 *
105 RCL 12
106 +
107 STO 05
108 RCL 11
109 2
110 /
111 -
112 ST* 07
113 ST* 08
114 ST* 06
115 RCL 07
116 ST+ 03
117 RCL 08
118 ST+ 04
119 RCL 05
120 RTN

121♦LBL E
122 13
123 STO 10
124 0
125 STO 00
126 STO 03
127 STO 04
128 END
```

```
01♦LBL "ZS-4/5"
02 "DATA?"
03 PROMPT
04 ΣREG 01
05 CLΣ
06 0

07♦LBL 01
08 STOP
09 Σ+
10 GTO 01

11♦LBL D
12 XEQ "ZA"
13 RCL 15
14 9
15 *
16 2
17 /
18 1/X
19 STO 49
20 SQRT
21 *
22 RCL 49
23 -
24 1
25 +
26 3
27 Y↑X
28 RCL 15
29 *
30 GTO 03

31♦LBL a
32 XEQ "HYP"

33♦LBL A
34 RCL 37
35 STO 40
36 RCL 38
37 RCL 06
38 SQRT
39 /
40 STO 32
41 1/X
42 RCL 40
43 RCL 34
44 -
45 *
46 STO 30
47 FS? 05
48 GTO 04
49 RCL 06
50 1
51 -
52 STO 15
53 FS? 04
54 GTO 02
55 STOP
56 STO 31
57 XEQ "CI"
58 STOP

59♦LBL 02
60 RCL 30
61 XEQ "TF"
62 XEQ "PVAL"
63 STOP

64♦LBL c
65 XEQ "HYP"

66♦LBL C
67 RCL 38
68 X↑2
69 STO 40
70 RCL 06
71 1
72 -
73 STO 15

74♦LBL 06
75 FS? 04
76 GTO 07

77♦LBL 03
78 STOP
79 RCL 15
80 RCL 40
81 *
82 STO 00
83 RCL 41
84 /
85 RCL 00
86 RCL 31
87 /
88 STOP

89♦LBL 07
90 RCL 40
91 *
92 RCL 34
93 /
94 STO 30
95 XEQ "CHISD"
96 XEQ "PVAL"
97 STOP

98♦LBL e
99 XEQ "HYP"

100♦LBL E
101 RCL 37
102 STO 40
103 RCL 06
104 2
105 *
106 STO 15
107 GTO 06

108♦LBL b
109 XEQ "HYP"

110♦LBL B
111 STO 00
112 SF 05
113 RCL 48
114 STO 38
115 GTO A

116♦LBL 04
117 CF 05
118 FS? 04
119 GTO 05
120 RCL 00
121 XEQ "ZA"
122 STO 31
123 XEQ "CI"
124 RTN

125♦LBL 05
126 XEQ "ZCDF"
127 XEQ "PVAL"
128 STOP

129♦LBL d
130 MEAN
131 STO 37
132 SDEV
133 STO 38
134 0
135 RTN
136 END
```

```
01♦LBL "ZS-6"
02 "DATA?"
03 PROMPT
04 STOP

05♦LBL "DEP"
06 SF 01
07 11
08 GTO 00

09♦LBL "DEI"
10 CF 01
11 12

12♦LBL 00
13 ΣREG 01
14 STO 10
15 CLΣ
16 0

17♦LBL 13
18 STOP
19 FS? 01
20 -
21 Σ+
22 GTO 13

23♦LBL "X TO Y"
24 MEAN
25 STO 47
26 SDEV
27 STO 48
28 RCL 06
29 STO 13
30 CLΣ
31 0
32 GTO 13

33♦LBL d
34 GTO IND 10

35♦LBL 11
36 MEAN
37 STO 47
38 SDEV
39 STO 27
40 0
41 STO 37
42 CF 01
43 RTN

44♦LBL 12
45 MEAN
46 STO 37
47 SDEV
48 STO 38
49 0
50 STO 33
51 RTN

52♦LBL a
53 XEQ "HYP"

54♦LBL A
55 XEQ "DMS"
56 RCL 48
57 X↑2
58 RCL 13
59 /
60 STO 07
61 RCL 38
62 X↑2
63 RCL 06
64 /
65 STO 08
66 RCL 07
67 +
68 SQRT
69 XEQ 04
70 FS? 05
71 GTO 02
72 RCL 07
73 RCL 08
74 +
75 RCL 07
76 /
77 1/X
78 STO 09
79 CHS
80 1
81 +
82 X↑2
83 RCL 06
84 1
85 -
86 /
87 STO 00
88 RCL 09
89 X↑2
90 RCL 13
91 1
92 -
93 /
94 RCL 00
95 +
96 1/X
97 INT

98♦LBL 01
99 STO 15
100 FS? 04
101 GTO 03
102 STOP
103 STO 31
104 XEQ "CI"
105 STOP

106♦LBL 02
107 CF 05
108 RCL 30
109 XEQ "ZCDF"
110 XEQ "PVAL"
111 STOP

112♦LBL 03
113 RCL 30
114 XEQ "TF"
115 XEQ "PVAL"
116 STOP

117♦LBL 04
118 STO 32
119 RCL 40
120 RCL 34
121 -
122 RCL 32
123 /
124 STO 30
125 RTN

126♦LBL b
127 XEQ "HYP"

128♦LBL B
129 XEQ "DMS"
130 RCL 27
131 RCL 06
132 SQRT
133 /
134 XEQ 04
135 RCL 06
136 1
137 -
138 GTO 01

139♦LBL c
140 XEQ "HYP"

141♦LBL C
142 XEQ "DMS"
143 RCL 33
144 X≠0?
145 GTO 05
146 RCL 13
147 1
148 -
149 STO 15
150 RCL 48
151 X↑2
152 *
153 STO 00
154 RCL 06
155 1
156 -
157 ST+ 15
158 RCL 38
159 X↑2
160 *
161 RCL 00
162 +
163 RCL 15
164 /
165 SQRT
166 STO 33

167♦LBL 05
168 RCL 06
169 1/X
170 RCL 13
171 1/X
172 +
173 SQRT
174 RCL 33
175 *
176 XEQ 04
177 RCL 13
178 2
179 -
180 RCL 06
181 +
182 GTO 01

183♦LBL D
184 STO 36
185 RCL 48
186 RCL 38
187 /
188 X↑2
189 STO 30
190 RCL 13
191 1
192 -
193 STO 15
194 FS? 04
195 GTO 06
196 STOP

197♦LBL 06
198 RCL 06
199 1
200 -

201♦LBL 07
202 STO 16
203 FS? 04
204 GTO 08
205 STOP
206 RCL 41
207 RCL 30
208 *
209 ENTER↑
210 ENTER↑
211 RCL 30
212 RCL 31
213 /
214 CF 01
215 CF 02
216 RTN

217♦LBL 08
218 RCL 30
219 XEQ "FCDF"
220 XEQ "PVAL"
221 STOP

222♦LBL E
223 STO 23
224 RCL 47
225 RCL 37
226 /
227 STO 30
228 RCL 13
229 2
230 *
231 STO 15
232 FS? 04
233 GTO 09
234 STOP

235♦LBL 09
236 RCL 06
237 2
238 *
239 GTO 07
240 END
```

```
01♦LBL "ZS-7"
02 0
03 STOP

04♦LBL C
05 XEQ "ZA"
06 STO 31
07 RCL 06
08 STO 00
09 RCL 40
10 XEQ 03
11 RCL 31
12 XEQ "CI"
13 STO 05
14 X<>Y
15 STO 04
16 X<>Y
17 X>0?
18 GTO 01
19 0
20 STO 05

21♦LBL 01
22 RCL 04
23 1
24 X>Y?
25 GTO 02
26 ENTER↑

27♦LBL 02
28 RDN
29 RCL 05
30 RTN

31♦LBL 03
32 ENTER↑
33 ENTER↑
34 1
35 -
36 CHS
37 *
38 RCL 00
39 /
40 SQRT
41 STO 32
42 RTN

43♦LBL B
44 RCL 40
45 RCL 06
46 *
47 RND
48 STO 10
49 RCL 06
50 -
51 CHS
52 STO 22
53 1
54 +
55 2
56 *
57 STOP
58 RCL 10
59 2
60 *
61 STOP
62 RCL 10
63 1
64 +
65 STO 19
66 2
67 *
68 STOP
69 RCL 06
70 RCL 10
71 -
72 STO 22
73 2
74 *
75 STOP
76 RCL 19
77 RCL 41
78 *
79 ENTER↑
80 ENTER↑
81 RCL 22
82 +
83 /
84 STO 04
85 RCL 22
86 1
87 +
88 RCL 31
89 *
90 RCL 10
91 +
92 1/X
93 RCL 10
94 *
95 STO 05
96 RCL 04
97 X<>Y
98 RTN

99♦LBL b
100 STO 20
101 STOP
102 STO 34
103 RCL 06
104 RCL 40
105 *
106 RND
107 STO 30
108 RCL 20
109 X>Y?
110 GTO 05
111 1
112 X≠Y?
113 GTO 04
114 CHS
115 RCL 30
116 +
117 STO 30

118♦LBL 04
119 RCL 30
120 XEQ "BINF"
121 XEQ "PVAL"
122 STOP

123♦LBL 05
124 1
125 STOP

126♦LBL c
127 STO 34
128 RCL 40
129 -
130 CHS
131 STO 23
132 RCL 06
133 STO 00
134 RCL 34
135 XEQ 03
136 RCL 23
137 X<>Y
138 /

139♦LBL 06
140 STO 30
141 XEQ "ZCDF"
142 XEQ "PVAL"
143 STOP

144♦LBL A
145 XEQ "ZA"
146 STO 31
147 XEQ "DMS"
148 RCL 13
149 STO 00
150 RCL 47
151 XEQ 03
152 X↑2
153 STO 27
154 RCL 06
155 STO 00
156 RCL 37
157 XEQ 03
158 X↑2
159 RCL 27
160 +
161 SQRT
162 STO 32
163 RCL 31
164 XEQ "CI"
165 STOP

166♦LBL a
167 STO 28
168 RCL 13
169 1/X
170 RCL 06
171 1/X
172 +
173 STO 33
174 RCL 13
175 STO 00
176 RCL 47
177 *
178 ENTER↑
179 RCL 06
180 ST+ 00
181 RCL 37
182 *
183 +
184 RCL 00
185 /
186 STO 00
187 1
188 -
189 CHS
190 ST* 00
191 RCL 00
192 ST* 33
193 XEQ "DMS"
194 RCL 33
195 SQRT
196 STO 32
197 /
198 GTO 06
199 END
```

```
01♦LBL "ZS-8"
02 FIX 4
03 STOP

04♦LBL A
05 STO 30
06 RCL 03
07 STO 15
08 RCL 02
09 RCL 11
10 STO 16
11 /
12 STO 48
13 RCL 30
14 XEQ "FCCDF"
15 STO 31
16 RTN

17♦LBL e
18 0
19 STO 53
20 STO 54
21 STO 50

22♦LBL 01
23 STOP
24 STO 51
25 STOP
26 STO 52
27 STOP
28 1/X
29 RCL 51
30 X↑2
31 *
32 ST+ 53
33 RCL 51
34 RCL 52
35 *
36 ST+ 50
37 1
38 ST+ 54
39 RCL 54
40 GTO 01

41♦LBL a
42 ENTER↑
43 RCL 03
44 *
45 RCL 48
46 *
47 RCL 53
48 *
49 SQRT
50 STO 49
51 RCL 50
52 +
53 LASTX
54 RCL 49
55 -
56 RTN

57♦LBL C
58 STO 57
59 RCL 12
60 RCL 14
61 STO 58
62 STO 16
63 /
64 RCL 07
65 /
66 STO 56
67 RCL 14
68 RCL 12
69 /
70 1/X
71 STOP
72 RCL 15
73 STO 59
74 ST* 16
75 RCL 13
76 /
77 1/X
78 STOP
79 RCL 07
80 STO 48
81 STOP
82 RCL 58
83 STO 15
84 RCL 56
85 XEQ "FCCDF"
86 STO 30
87 RCL 59
88 STO 15
89 RCL 30
90 STOP
91 RCL 57
92 XEQ "FCCDF"
93 RTN

94♦LBL E
95 0
96 STO 53
97 STO 50
98 STO 54

99♦LBL 02
100 STOP
101 STO 51
102 X↑2
103 ST+ 53
104 STOP
105 STO 52
106 RCL 51
107 *
108 ST+ 50
109 1
110 ST+ 54
111 RCL 54
112 GTO 02

113♦LBL D
114 ENTER↑
115 RCL 58
116 *
117 RCL 48
118 *
119 RCL 53
120 *
121 RCL 59
122 1
123 +
124 /

125♦LBL 03
126 SQRT
127 STO 49
128 RCL 50
129 +
130 LASTX
131 RCL 49
132 -
133 RTN

134♦LBL d
135 RCL 59
136 *
137 RCL 48
138 *
139 RCL 53
140 *
141 RCL 58
142 1
143 +
144 /
145 GTO 03

146♦LBL H
147 XROM "ΣAOVONE"

148♦LBL I
149 XROM "ΣAOVTWO"
150 .END.
```

```
01◆LBL "ZS-9"
02 0
03 FIX 4
04 STOP

05◆LBL D
06 ΣREG 01
07 CLRG
08 0

09◆LBL 01
10 STOP
11 Σ+
12 GTO 01

13◆LBL e
14 RCL 06
15 1
16 -
17 STO 14
18 1
19 -
20 STO 15
21 SDEV
22 X↑2
23 RCL 14
24 *
25 STO 07
26 RDN
27 X↑2
28 RCL 14
29 *
30 STO 08
31 RCL 07
32 *
33 SQRT
34 ENTER↑
35 XEQ "OP12"
36 X<>Y
37 RCL 44
38 *
39 RCL 08
40 SQRT
41 *
42 RCL 07
43 SQRT
44 *
45 CHS
46 RCL 07
47 +
48 RCL 15
49 /
50 SQRT
51 STO 33
52 X↑2
53 RCL 04
54 *
55 RCL 06
56 /
57 RCL 08
58 /
59 SQRT
60 STO 36
61 RCL 33
62 RCL 08
63 SQRT
64 /
65 STO 35
66 RCL 15
67 STOP
68 STO 31
69 RTN

70◆LBL "OP13"
71 RCL 05
72 RCL 06
73 *
74 ENTER↑
75 ENTER↑
76 RCL 01
77 RCL 03
78 *
79 -
80 RCL 06
81 /
82 LASTX
83 1
84 -
85 /
86 ENTER↑
87 ENTER↑
88 SDEV
89 RDN
90 /
91 R↑
92 /
93 STO 44
94 RTN

95◆LBL "OP12"
96 XEQ "OP13"
97 ENTER↑
98 ENTER↑
99 SDEV
100 RDN
101 /
102 R↑
103 *
104 STO 45
105 ENTER↑
106 ENTER↑
107 MEAN
108 STO 48
109 RDN
110 STO 47
111 *
112 CHS
113 R↑
114 +
115 STO 46
116 RCL 45
117 X<>Y
118 RTN

119◆LBL "OP14"
120 RCL 45
121 *
122 RCL 46
123 +
124 RTN

125◆LBL "OP15"
126 RCL 46
127 -
128 RCL 45
129 /
130 RTN

131◆LBL A
132 RCL 31
133 RCL 35
134 *
135 STO 39
136 RCL 45
137 STO 40

138◆LBL 02
139 RCL 39
140 +
141 RCL 40
142 LASTX
143 -
144 STOP

145◆LBL B
146 RCL 31
147 RCL 36
148 *
149 STO 39
150 RCL 46
151 STO 40
152 GTO 02

153◆LBL C
154 XEQ 04

155◆LBL 03
156 RCL 31
157 *
158 STO 39
159 RCL 00
160 XEQ "OP14"
161 STO 40
162 GTO 02

163◆LBL c
164 XEQ 04
165 X↑2
166 RCL 33
167 X↑2
168 +
169 SQRT
170 STO 37
171 GTO 03

172◆LBL 04
173 STO 00
174 RCL 47
175 -
176 X↑2
177 RCL 08
178 /
179 RCL 06
180 1/X
181 +
182 SQRT
183 RCL 33
184 *
185 STO 38
186 RTN

187◆LBL a
188 XEQ "HYP"
189 RCL 45
190 -
191 CHS
192 RCL 35
193 /

194◆LBL 05
195 STO 30
196 XEQ "TF"
197 XEQ "PVAL"
198 STOP

199◆LBL b
200 XEQ "HYP"
201 RCL 46
202 -
203 CHS
204 RCL 36
205 /
206 GTO 05

207◆LBL E
208 STO 28
209 0
210 STO 34
211 RCL 44
212 STO 40
213 X↑2
214 1
215 -
216 CHS
217 SQRT
218 1/X
219 RCL 15
220 SQRT
221 *
222 RCL 40
223 *
224 GTO 05

225◆LBL d
226 RCL 48
227 -
228 STO 43
229 X↑2
230 RCL 08
231 /
232 STO 00
233 RCL 33
234 RCL 31
235 *
236 X↑2
237 RCL 08
238 /
239 RCL 45
240 X↑2
241 -
242 CHS
243 STO 42
244 RCL 06
245 /
246 RCL 42
247 +
248 RCL 00
249 +
250 0
251 X>Y?
252 GTO 06
253 X<>Y
254 SQRT
255 RCL 31
256 *
257 RCL 33
258 *
259 RCL 42
260 /
261 STO 39
262 RCL 45
263 RCL 43
264 *
265 RCL 42
266 /
267 RCL 47
268 +
269 STO 40
270 GTO 02

271◆LBL 06
272 "ALL REALS"
273 AVIEW
274 RTN
275 END
```

```
01•LBL "ZS-10"
02 FIX 4
03 CF 01
04 CF 04
05 0
06 STOP

07•LBL e
08 RCL 41
09 STO 07
10 RCL 01
11 STO 46
12 RCL 42
13 STO 11
14 RCL 02
15 STO 47
16 RCL 43
17 STO 12
18 RCL 03
19 STO 43
20 RCL 33
21 STO 01
22 RCL 33
23 STO 02
24 RCL 31
25 STO 03
26 3
27 -
28 STO 15
29 RCL 32
30 STO 04
31 RCL 35
32 STO 05
33 RCL 36
34 STO 06
35 RCL 30
36 STO 13
37 RCL 03
38 RCL 05
39 *
40 RCL 02
41 *
42 STO 49
43 2
44 RCL 04
45 *
46 RCL 01
47 *
48 RCL 06
49 *
50 ST+ 49
51 RCL 03
52 RCL 06
53 X↑2
54 *
55 ST- 49
56 RCL 04
57 X↑2
58 RCL 02
59 *
60 ST- 49
61 RCL 01
62 X↑2
63 RCL 05
64 *
65 ST- 49
66 RCL 13
67 STO 33
68 RCL 46
69 RCL 07
70 *
71 ST- 33
72 RCL 47
73 RCL 11
74 *
75 ST- 33
76 RCL 48
77 RCL 12
78 *
79 ST- 33
80 RCL 33
81 RCL 15
82 /
83 SQRT
84 STO 33
85 RCL 05
86 RCL 02
87 *
88 RCL 06
89 X↑2
90 -
91 RCL 49
92 /
93 SQRT
94 RCL 33
95 *
96 STO 36
97 RCL 03
98 RCL 02
99 *
100 RCL 01
101 X↑2
102 -
103 RCL 49
104 /
105 SQRT
106 RCL 33
107 *
108 STO 37
109 RCL 03
110 RCL 05
111 *
112 RCL 04
113 X↑2
114 -
115 RCL 49
116 /
117 SQRT
118 RCL 33
119 *
120 STO 38
121 RCL 07
122 RCL 03
123 /
124 STO 08
125 RCL 27
126 STO 44
127 RCL 15
128 STOP
129 STO 31
130 RTN

131•LBL A
132 RCL 46
133 STO 40
134 RCL 31
135 RCL 36
136 *
137 STO 39

138•LBL 01
139 RCL 40
140 +
141 ENTER↑
142 ENTER↑
143 RCL 39
144 2
145 *
146 -
147 RTN

148•LBL B
149 RCL 47
150 STO 40
151 RCL 31
152 RCL 37
153 *
154 STO 39
155 GTO 01

156•LBL C
157 RCL 48
158 STO 40
159 RCL 31
160 RCL 38
161 *
162 STO 39
163 GTO 01

164•LBL a
165 XEQ "HYP"
166 RCL 46
167 -
168 CHS
169 RCL 36
170 /

171•LBL 02
172 STO 38
173 XEQ "TF"
174 XEQ "PVAL"
175 STOP

176•LBL b
177 XEQ "HYP"
178 RCL 47
179 -
180 CHS
181 RCL 37
182 /
183 GTO 02

184•LBL c
185 XEQ "HYP"
186 RCL 48
187 -
188 CHS
189 RCL 38
190 /
191 GTO 02

192•LBL E
193 RCL 47
194 *
195 STO 00
196 0
197 STOP
198 RCL 48
199 *
200 ST+ 00
201 RCL 46
202 ST+ 00
203 RCL 00
204 RTN

205•LBL D
206 RCL 46
207 STOP
208 RCL 47
209 STOP
210 RCL 40
211 STOP

212•LBL d
213 XROM "ΣMLRXY"
214 END
```

```
01•LBL "ZSTAT"
02 "ZSTAT"
03 PROMPT
04 RTN

05•LBL "ZCDF"
06 STO 25
07 ENTER↑
08 *
09 2
10 /
11 CHS
12 E↑X
13 PI
14 2
15 *
16 SQRT
17 /
18 STO 26
19 RCL 25
20 X<0?
21 GTO 02
22 SF 00

23•LBL 01
24 1
25 RCL 25
26 .2316419
27 *
28 +
29 1/X
30 ENTER↑
31 ENTER↑
32 ENTER↑
33 1.330274429
34 *
35 -1.821255978
36 +
37 *
38 1.781477937
39 +
40 *
41 -.356563782
42 +
43 *
44 .31938153
45 +
46 *
47 RCL 26
48 *
49 FS? 00
50 GTO 03
51 RTN

52•LBL 02
53 RCL 25
54 CHS
55 STO 25
56 XEQ 01
57 1
58 X<>Y
59 -

60•LBL 03
61 CF 00
62 ENTER↑
63 1
64 -
65 CHS
66 RTN

67•LBL "ZA"
68 .5
69 X<>Y
70 X>Y?
71 XEQ 04
72 ENTER↑
73 *
74 1/X
75 LN
76 SQRT
77 STO 25
78 .010328
79 *
80 .802853
81 +
82 RCL 25
83 *
84 2.515517
85 +
86 RCL 25
87 .001308
88 *
89 .189269
90 +
91 RCL 25
92 *
93 1.432788
94 +
95 RCL 25
96 *
97 1
98 +
99 /
100 RCL 25
101 X<>Y
102 -
103 FS? 01
104 CHS
105 GTO 05

106•LBL 04
107 SF 01
108 1
109 -
110 CHS
111 RTN

112•LBL 05
113 CF 01
114 RTN

115•LBL "CHISD"
116 STO 30
117 40
118 RCL 15
119 X>Y?
120 GTO 10
121 1
122 STO 23
123 X<>Y
124 2
125 /
126 STO 21
127 INT
128 LASTX
129 X≠Y?
130 GTO 06
131 1
132 -
133 FACT
134 STO 23
135 GTO 06

136•LBL 06
137 .5
138 X=Y?
139 GTO 07
140 X<>Y
141 1
142 -
143 ST* 23
144 GTO 06

145•LBL 07
146 PI
147 SQRT
148 ST* 23

149•LBL 08
150 RCL 30
151 RCL 21
152 1
153 -
154 Y↑X
155 RCL 30
156 2
157 /
158 CHS
159 E↑X
160 *
161 2
162 RCL 21
163 Y↑X
164 /
165 RCL 23
166 /
167 STO 25
168 RCL 30
169 RCL 21
170 /
171 ST* 25
172 2
173 RCL 21
174 *
175 STO 26
176 1
177 STO 24

178•LBL 09
179 RCL 30
180 RCL 26
181 2
182 +
183 STO 26
184 /
185 RCL 24
186 *
187 STO 24
188 +
189 X≠Y?
190 GTO 09
191 RCL 25
192 *
193 RTN

194•LBL 10
195 9
196 *
197 2
198 /
199 1/X
200 STO 29
201 RCL 30
202 RCL 15
203 /
204 3
205 1/X
206 Y↑X
207 1
208 -
209 RCL 29
210 +
211 RCL 29
212 SQRT
213 /
214 XEQ "ZCDF"
215 RTN

216•LBL "FCCDF"
217 STO 17
218 RCL 15
219 2
220 /
221 FRC
222 0
223 X≠Y?
224 SF 01
225 RCL 16
226 2
227 /
228 FRC
229 0
230 X≠Y?
231 SF 02
232 FS? 01
233 GTO 16
234 FS? 02
235 GTO 11
236 RCL 15
237 RCL 16
238 X<=Y?
239 GTO 17

240•LBL 11
241 CF 02
242 RCL 15
243 STO 18
244 RCL 16
245 STO 19
246 STO 25
247 XEQ 15
248 STO 20
249 CHS
250 STO 21

251•LBL 12
252 RCL 18
253 2
254 /
255 STO 00
256 1
257 ST+ 21
```

```
258 STO 22
259 STO 23
260 STO 24

261•LBL 13
262 RCL 22
263 RCL 00
264 X<=Y?
265 GTO 14
266 X<>Y
267 1/X
268 RCL 21
269 *
270 RCL 19
271 *
272 2
273 ST+ 19
274 /
275 ST* 23
276 1
277 ST+ 22
278 RCL 23
279 ST+ 24
280 GTO 13

281•LBL 14
282 RCL 20
283 SQRT
284 ENTER↑
285 RCL 25
286 Y↑X
287 RCL 24
288 *
289 RTN

290•LBL 15
291 RCL 15
292 RCL 16
293 /
294 RCL 17
295 *
296 1
297 +
298 1/X
299 RTN

300•LBL 16
301 CF 01
302 FS? 02
303 GTO 18

304•LBL 17
305 RCL 16
306 STO 18
307 RCL 15
308 STO 19
309 STO 25
310 XEQ 15
311 STO 21
312 CHS
313 STO 20
314 1
315 ST+ 20
316 ST- 21
317 XEQ 12
318 CHS
319 1
320 +
321 RTN

322•LBL 18
323 CF 02
324 RCL 17
325 RCL 15
326 *
327 RCL 16
328 /
329 SQRT
330 RAD
331 ATAN
332 STO 17
333 SIN
334 STO 20
335 RCL 17
336 COS
337 STO 21
338 STO 22
339 STO 23
340 DEG
341 1
342 STO 24
343 STO 25
344 RCL 16
345 X=Y?
346 GTO 21
347 2
348 -
349 STO 14

350•LBL 19
351 RCL 14
352 RCL 25
353 X=Y?
354 GTO 20
355 2
356 ST+ 25
357 RCL 21
358 X↑2
359 RCL 24
360 *
361 2
362 *
363 RCL 25
364 /
365 ST* 23
366 RCL 23
367 ST+ 22
368 1
369 ST+ 24
370 GTO 19

371•LBL 20
372 RCL 20
373 ST* 22
374 RCL 22
375 ST+ 17

376•LBL 21
377 1
378 STO 22
379 1
380 STO 24
381 RCL 15
382 X=Y?
383 GTO 26
384 RDN
385 RCL 16
386 X=Y?
387 GTO 23
388 STO 23

389•LBL 22
390 1
391 ST- 23
392 RCL 23
393 ST* 24
394 1
395 ST- 23
396 RCL 23
397 ST/ 24
398 X≠Y?
399 GTO 22

400•LBL 23
401 RCL 21
402 ENTER↑
403 RCL 16
404 Y↑X
405 RCL 20
406 *
407 ST* 24
408 RCL 16
409 1
410 STO 26
411 STO 27
412 -
413 STO 25

414•LBL 24
415 2
416 ST+ 25
417 ST+ 26
418 RCL 26
419 RCL 15
420 X<=Y?
421 GTO 25
422 RCL 26
423 1/X
424 RCL 25
425 *
426 RCL 20
427 X↑2
428 *
429 ST* 27
430 RCL 27
431 ST+ 22
432 GTO 24

433•LBL 25
434 RCL 22
435 RCL 24
436 *
437 ST- 17

438•LBL 26
439 RCL 17
440 2
441 *
442 PI
443 /
444 1
445 -
446 CHS
447 RTN

448•LBL "FCDF"
449 XEQ "FCCDF"
450 1
451 -
452 CHS
453 RTN

454•LBL "BINF"
455 STO 00
456 1
457 +
458 STO 35
459 2
460 *
461 STO 15
462 RCL 06
463 RCL 00
464 -
465 ST/ 35
466 2
467 *
468 STO 16
469 RCL 35
470 1/X
471 RCL 34
472 *
473 1
474 RCL 34
475 -
476 /
477 XEQ "FCCDF"
478 RTN

479•LBL "TF"
480 STO 30
481 40
482 RCL 15
483 X>Y?
484 GTO 28
485 STO 16
486 1
487 STO 15
488 RCL 30
489 X↑2
490 XEQ "FCCDF"
491 2
492 /
493 STO 00
494 RCL 16
495 STO 15
496 RCL 30
497 0
498 X>Y?
499 GTO 27
500 RCL 00
501 1
502 -
503 CHS
504 RTN

505•LBL 27
506 RCL 00
507 RTN

508•LBL 28
509 RCL 30
510 GTO "ZCDF"

511•LBL "CI"
512 RCL 32
513 *
514 STO 39
515 RCL 40
516 +
517 ENTER↑
518 ENTER↑
519 RCL 39
520 2
521 *
522 -
523 RTN

524•LBL "HYP"
525 STO 28
526 STOP
527 STO 34
528 SF 04
529 RTN

530•LBL "PVAL"
531 STO 29
532 CF 04
533 RCL 28
534 X<0?
535 GTO 30
536 X≠0?
537 GTO 29
538 RDN
539 2
540 *
541 1
542 X>Y?
543 GTO 30
544 RDN
545 2
546 -
547 CHS
548 RTN

549•LBL 29
550 RDN
551 1
552 -
553 CHS
554 RTN

555•LBL 30
556 RDN
557 RTN

558•LBL "DMS"
559 RCL 47
560 RCL 37
561 -
562 STO 40
563 END
```

DISTRIBUTION LIST

	NO. OF COPIES
Library, Code 0142 Naval Postgraduate School Monterey, CA 93943	4
Office of Research Administration Code 012A Naval Postgraduate School Monterey, CA 93943	1
Library, Code 55 Naval Postgraduate School Monterey, CA 93943	1
Professor P. W. Zehna Code 55Ze Naval Postgraduate School Monterey, CA 93943	10
Professor D. R. Barr Code 55Bn Naval Postgraduate School Monterey, CA 93943	1
Professor R. Shudde Code 55Su Naval Postgraduate School Monterey, CA 93943	1
Professor P. A. W. Lewis Code 55Lw Naval Postgraduate School Monterey, CA 93943	1